FAULT DETECTION AND DIAGNOSTICS OF FAILURES

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Contents

Summary

In the present section, the basis, purpose and principles of the technical objects, machines and systems, are discussed. The technical diagnostics influence on the objects' reliability and forecast of operation, as well as its role in the object quality increase are described. The organization principles at all stages of machine/system service life are considered.

1. Basic Concepts

Technical diagnostics constitutes the theory, methods and means to search and detect failures (defects) of technical objects. By a defect is implied any discrepancy of the object properties to those specified, required or anticipated. To detect a defect means to ascertain the fact of its presence or absence in the object. To search a defect means to determine its location in the object with a certain extent of precision.

The purpose of the technical diagnostics is to increase the reliability of the objects at the stages of their manufacture, operation and storage. Diagnostics allows us to increase the reliability of the functioning of the objects, their service life and mean time of operation between failures.

The requirements that should be met by the object, manufactured or in operation, are specified in appropriate technical documentation. The object meeting all the requirements of the documentation is a *serviceable* one or is in a *serviceable technical state*. The notion of *serviceability of the object* is important. The object is *serviceable* if it can perform *all prescribed functions* while the values of the required parameters (indications) remain within the specified limits. The object functions properly, if the values of its parameters (indicators), remain within the specified limits.

Defective and non-serviceable technical state as well as *the technical state of improper functioning* of the object can be detailed by indicating the defects that violate the serviceability or proper functioning and relate to one or several components of the object or to the object as a whole.

The detection and search of defects are the procedures for *determining the technical state* of the object and can be generalized by the term *diagnostics*; *diagnosis* is the result of diagnostics. The diagnostics of the technical state of any object is performed by various *diagnostics means*. Such means can be hardware or software; the operator, quality inspector or adjuster can act as diagnostics means as well. Interaction of diagnostics means and object forms a *diagnostics system*. There are systems for *test* and *functional diagnostics*. In test diagnostic systems the object is exposed to specifically arranged *test actions*. In the functional diagnostic systems, applied to objects in operation, the object is influenced only by *operation actions*, specified by its algorithm of functioning.

The diagnostics system, examining the technical state of the object, implements a certain *algorithm for* (*test* or *functional*) *diagnostics*. Diagnostics algorithm, in the general case, consists of a certain *set* of so-called *elementary checks* of the object, as well as the rules, setting the sequence of elementary checks and the rules for the analysis of elementary checks results. Each elementary check is specified by its test or operation action, applied or coming to the object, and *a number of check points*, which read the object response to such action.

Under the development of diagnostic systems one should bear in mind that they must be able to detect possible defects and their symptoms, as well as to select or build up an operation model of a serviceable object or its defective modifications.

Let us specify the notions of "control", "monitoring" and "diagnostics". By *control* the working-out and implementation of target-oriented (controlling) actions applied to the object are understood.

Monitoring means the process of collection and processing of data for the purpose of specifying the event. If such an event means that a certain object parameter reaches a certain preset value then the monitoring the parameters is considered. If a monitored event amounts to identification that the object is in serviceable / defective state or state of proper / improper functioning, then the technical state monitoring is considered.

The systems for test diagnostics are control systems that work out and implement specifically organized test (i.e. controlling) actions applied to the object to determine its technical state. The systems for functional diagnostics are typical monitoring systems, not requiring the target-oriented actions to be applied to the object.

From the above point of view, for instance, systems called nondestructive monitoring systems are classified as systems for test diagnostics, and vibration-acoustic systems for technical state monitoring are referred to as systems for functional diagnostics.

The formal model of an object is its description in the analog, graphical, tabular or other forms. For non-complex objects of diagnostics it is expedient to use the so-called explicit models, including both description of the serviceable object, and that of every defective modification. Non-explicit model of the diagnosed object implies a description, for instance, of a serviceable object, formalized models of defects and rules according to which one can finalize the descriptions of all the defective modifications of the object by using both the specified description and models of the defects.

Models of the objects are *functional* and *structural*. The former ones present only functions performed by the object (serviceable or defective), specified for inputs and outputs of the object, while the latter also include information about internal organization of the object and its structure. The functional models make it possible to perform tasks of checking the serviceability and proper functioning of the object. For checking serviceability and search of defects on a deeper level the structural models are used. Diagnostics models of the object can be *deterministic* and *probabilistic*. The probabilistic consideration is used when the deterministic one is not possible. The diagnostics objects models are required to construct diagnostics algorithm by formalized methods. The construction of diagnostics algorithm involves the selection of such a set of elementary checks, by which a serviceable state or a state of proper functioning of the object can be distinguished from its defective states in the task of defects detection.

When a diagnostics algorithm is constructed using explicit object models, the elementary checks are selected by means of one-couple comparison of those descriptions, the technical states of which need to be distinguished. In the tasks of test diagnostics a number of check points are specified as preliminary, being the same for all elementary checks. In such cases only input actions of elementary checks are chosen - these are tasks for *tests construction*. In the tasks of functional diagnostics, in contrast, the input actions of elementary checks are defined preliminary by the operating algorithm of the object functioning, and it is only check points that have to be selected.

To perform the same diagnostics task (for example, to check serviceability) several algorithms can be constructed differing either by the number of elementary checks, or the sequence in which they are implemented.

The necessity to increase the production rate in diagnostics operations, to decrease the time for detection, search and elimination of failures/defects, to reduce volumes and complexity of diagnostics means involves the development of *optimum algorithms*, requiring minimum expenses for their implementation.

Diagnostics means can be *hardware* and *software*, *external* or *built-in*, *manual*, *automated* or *automatic*, *specialized* or *multipurpose*.

The functional diagnostics means are built-in ones and thus are developed simultaneously with the object. The level of object checkability stipulates the efficiency of test diagnostics of their technical state and influences the production output and product quality; stipulates the availability coefficients and repair costs in the process of its operation.

Checkability is achieved by transforming the structure of the checked object, into the form convenient for diagnostics. For this purpose the additional built-in means for test diagnostics are incorporated into the object at the design stage.

The task of diagnostics is determination of the present technical state of the object. The other task of diagnostics is prediction of the object technical state at a certain moment of time in future. The tasks of the first type should be attributed to technical diagnostics, while those of the second type are attributed to technical prediction.

There is another kind of tasks which is concerned with the determination of the object technical state at some moment in the past (the tasks of the technical genetics). The tasks of the technical genetics arise, for instance, from the investigation of the accidents and their causes, when the technical state of the object at the time of investigation differs from that of the past as a result of some original cause that led to the accident. These tasks are performed by way of determination of the probable cause which led the object to its present state. The prediction tasks include problems related to the determination of the object service life or time intervals between inspections, maintenance measures and repairs and also referred to the prediction tasks. These tasks are solved by means of determining probable evolutions of the object state.

The solution of the prediction task is essential, in particular, for organization of *the maintenance of the objects with respect to the state* (instead of maintenance with respect to the resource). It is impossible to employ the methods which are used to solve diagnostics tasks to the solution of the prediction tasks due to the different models used. While in diagnostics task the model is usually an object’s description, then for prediction tasks we need to use a model of technical characteristics evolution of an object.

The main indicators of the quality of the diagnostic systems are guaranteed complete detection and thorough search of defects. When applied to machines diagnostics turns out to be rather effective, allowing us not only to clarify failures and low quality indices causes, but to help provide reliability at the stages of design and production (Figure 1).

In the course of maintenance and repair of machines diagnostics is necessary to improve maintenance, resource prediction, quality inspection of repair and design modernization. Diagnostics helps check serviceability and study aging and corrosion processes of stored equipment. Diagnostics increases the reliability thus improving such indices as suitability coefficient, serviceability recovery time, remaining service life, and time to failure. A proper organization of diagnostics reduces spoilage at all stages of production. Further, diagnostics is implemented at all stages of machine life cycle: design, manufacture, and operation.

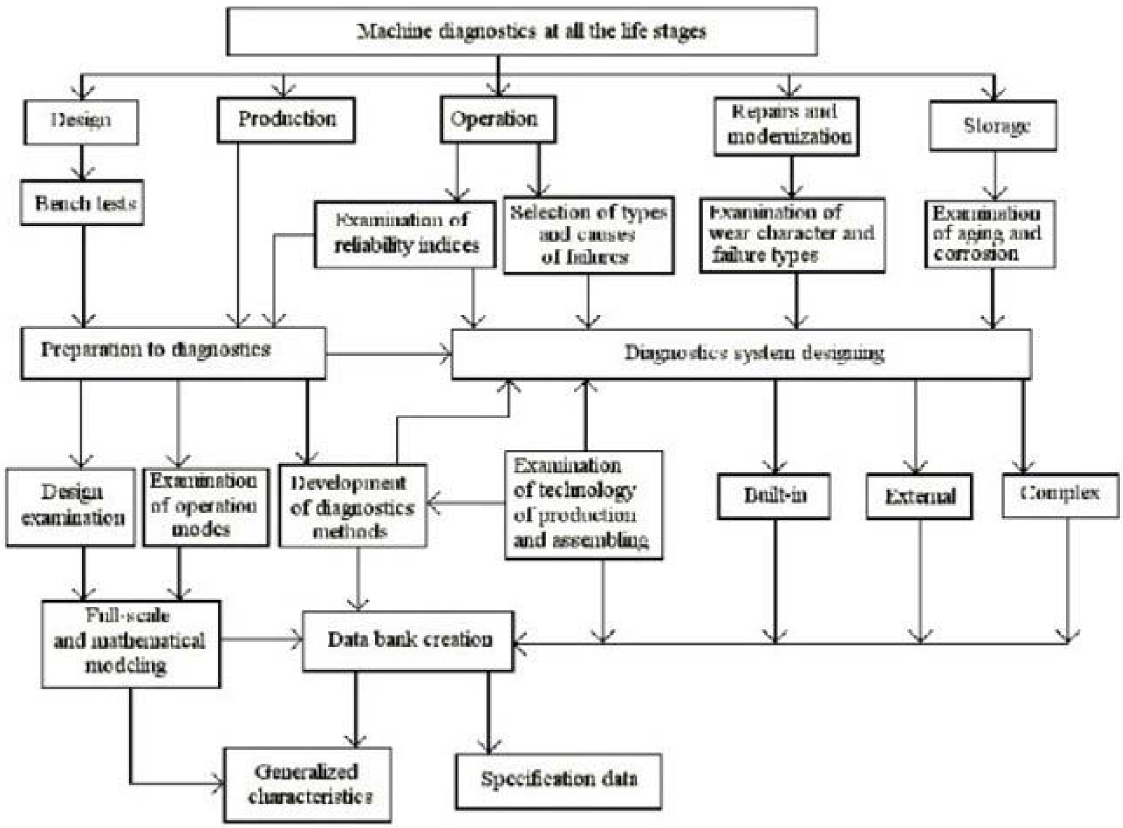

Figure 1. Specific features of the machine diagnostics at all life stages

With respect to tasks performed by technical diagnostics at the production stage, the periods of acceptance of completed items and materials, manufacturing process, adjustment and acceptance of machine can be outlined. For the operation period typical stages are as follows: machine operation period for the purpose it was designed, maintenance (regular measures, measures prior to/after the operation period for the designated purpose), repairs, transportation and storage.

A diagnostics system, while examining the technical state of the object, implements a certain algorithm for test or functional diagnostics. The elementary check gives machine response signals at a number of check points. The diagnosis takes into consideration a number of elementary check results.

To develop diagnostic systems the following problems should be solved: examination of the tested object, its possible defects and the symptoms of their existence, making a model for both a serviceable object and its defective modifications behavior, analytical treatment of the model to get the diagnostics algorithm, implemented by the system, selection or working-out of diagnostics means, calculation of the diagnostics system characteristics as a whole. The development of diagnostic systems for complex objects may require return to previous stages of development and to reconsider previously adopted solutions. Here the problems to provide object’s checkability play a significant role.

The efficiency of diagnostics processes, estimated, for instance, by diagnostics time or apparatus costs for storage and implementation of diagnostics algorithms, in some cases essentially depends on the quality of the latter.

The necessity to increase the production rate in the process of diagnostics operations, to reduce time for detection, search and elimination of failures and to reduce the complexity of diagnostics means motivates methods of creating optimum algorithms, requiring minimum costs for their implementation. The construction of optimum algorithms in many cases entails large volumes of calculation, therefore in many cases it would be enough to use optimum diagnostics algorithms, which despite reduced expenses for implementation, may not necessarily give a minimum.

The efficiency of diagnostics processes depends not only on diagnostics algorithm quality, but also on diagnostics means quality. The requirement to ensure high checkability sophisticates the design of a machine and may entail large additional costs for diagnostics.

Checkability is made possible as a result of converting the structure of the tested machine into a form convenient for diagnostics. For this purpose additional devices (built-in test diagnostics means) are introduced into machine design.

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Biographical Sketches

Klyuev Vladimir V. was born on January 2, 1937, Moscow, Russia. He graduated from the Moscow State Technical University named after Bauman in 1960 and Received the Degree of Candidate of Technical Sciences in 1964 and the Degree of Doctor of Technical Sciences in 1973.

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President of the Scientific Council on Automated Systems of Diagnostics of the Russian Academy of Sciences, President of the Russian Society for Non-Destructive Testing and Technical Diagnostics, Member of Editorial Board of journal "Defectoscopiya", Editor-in-chief of Journal "Testing. Diagnostics."

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