DIAGNOSTIC SYSTEM OF MACHINE EXPLOITATION

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Abstract

This work presents the main descriptors of the diagnostic system of machine exploitation. This problem contains: the measurements of technical state symptoms, the determination of their boundary values, and the frequency of diagnostics. This problem and the tasks in the system of machine exploitation supported with computer techniques constitutes about the rank of the discussed problem.

Keywords: machine diagnostics, symptoms of the state, boundary value, frequency of diagnostics

1. Introduction

The knowledge of the machine's technical state results from the need of making rational decisions about the "quality", and further treatment of the machine. It can be a decision on further use, on undertaking appropriate preventive interventions, or on the introduction of construction, technology or exploitation changes.

Discussed in this work are chosen problems of machine state diagnosis, emphasizing the problems of the new strategy of machine exploitation, including state symptoms, determination of the boundary value of measured symptoms, and determining deadlines of consecutive terms of diagnosis.

The introduction of diagnostic systems makes it possible to improve the organization and management of machine usage in industrial institutions with the help of computer technology.

2. Main problems in machine diagnostics

The growing level of complexity of machines and criticality of their function within safety and economics, force constructors and users of these objects to know their current technical state, and to use them considering prognosis. This is possible, if at construction stage equipment and diagnostic procedures are integrated with the object.

Generation of vibration signals in the description of machine condition changes.

Evaluation of the machine dynamic state with the use of generated by them physical processes requires the association of functional parameters of the evaluated object with the set of measures and the opinions of output processes.

While functioning of the machines, in the consequence of the existence of a number of external factors (environmental forcing, from different machines) and internal (aging, wastes, co-operation of

elements), there are disorders of balance state in the machine, which spread in a springy medium – the material of which the machine is built.

The disorder has dynamic character and sustain the conditions of balance between the state of among the condition inertia, elasticity, the suppression and extortion.

The disorder spreads from the source in the form of waves in the way dependent from physical properties, and the configuration borders, dimensions and shape of the machine. This in result causes wave energy scattering, their bending, reflection and mutual superposition. The existence of sources and spreading of disorders causes the occurrence of vibrations of machine elements and the surrounding environment. These processes are the basis of building a model of signal generation determining the manner of constructing, functioning and state changes of the object.

The sequence of assumptions leading to the signal generation model can be presented with the use of a cybernetic model, as in the Fig. 1.
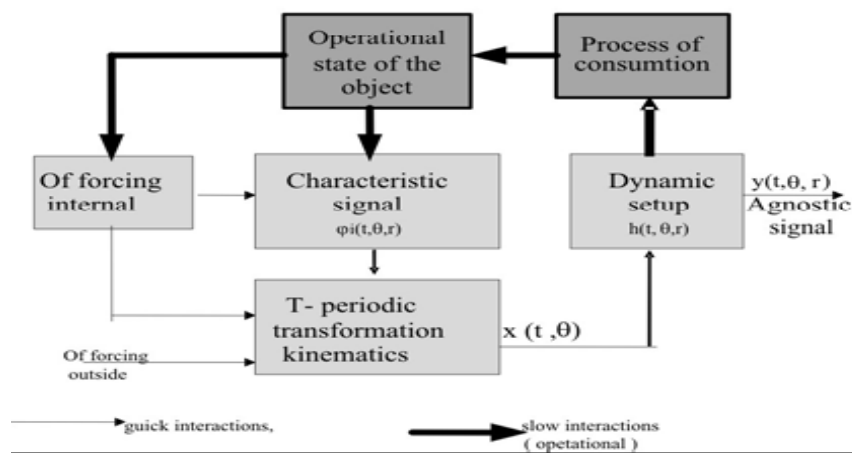

Fig.1 Model of diagnostic signal generation of a machine

The presented way of interpreting the signal $y(\Theta,r)$ is, in a general case of machines of periodic working, true, but not always as simple as in the Fig. 2.
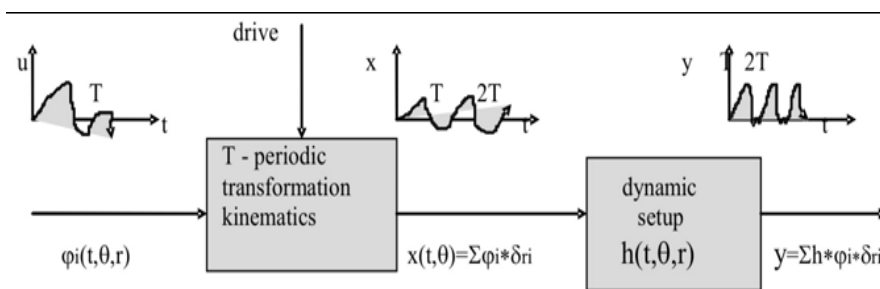

Fig.2. Transformation of the characteristic signal φ_i into the output signal y
as the model of signal generation in machines [2]

The example of such formulation of the problem is the main transmission of the bridge of a vehicle whose generation model is presented in the Fig. 3.

The received output signal in any place of the transmission casing is a weighed sum of answers to all elementary events $Un(t, ,r)$, occurring always in the same sequence in separate dynamic partial systems of impulse function of transition $hn(t, \Theta ,r)$. These effects, after going through certain

dynamic systems, sum up and undergo an additional deformation on the transmission corpse, whilst the change of place of receiving the "r" signal is also connected with the transmittance change.

The notion $n(t, \Theta)$ describes a random effect occurring because of the existence of dynamic micro-phenomena, such as friction, roughness, etc. The output signal of any receiving point can be approximately expressed with the equation:

$$y_k(\theta,r) = \Sigma \, a \, (k) \, h_i \, (t,\theta,r) * [u_i \, (t,\theta,r) + n \, (t,\theta,r)] \tag{1}$$

where: the impulse transition function $h(*)$ corrupts also the properties of the corpse, $a(k)$ gives different weighs of summing connected with the receiving point "r".

Main problems of machine diagnostics include:
- acquiring and processing diagnostic information;
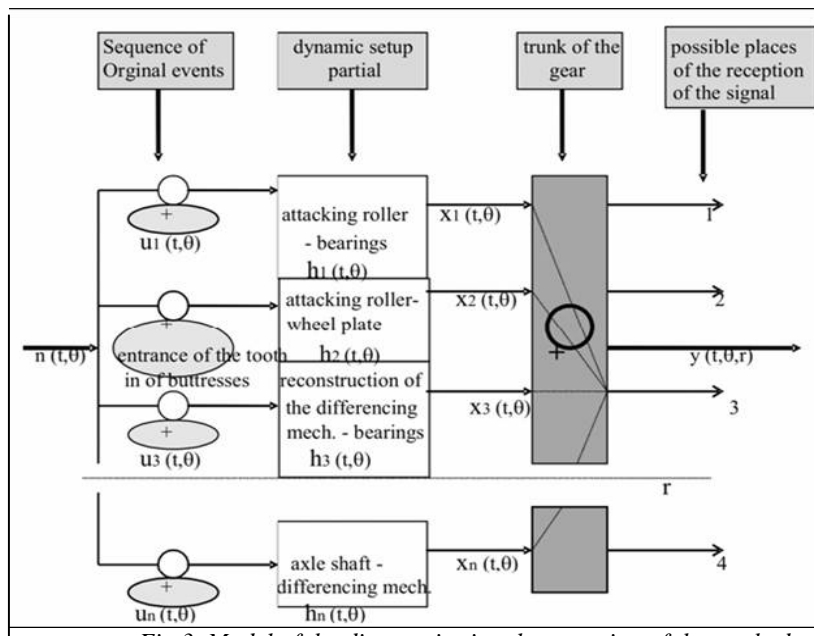- building of models and diagnostic reports;

Fig.3. Model of the diagnostic signal generation of the toothed transmission

- the diagnostic inference and boundary value;
- the classification of machine state;
- the expected time of next diagnosis;
- presenting the decision information.

Measuring system for the aims of the modern diagnostics of machines consists of two basic elements:
- the equipment in which distinguished are the modules: conditioning subsystem and processing of signals, the subsystem of processing signals of the phase gauge, the subsystem of the industrial computer, the subsystem of power supply,
- the software, consisting of the modules: operating system (VxWorks), the software of the modules of signal processing and analysis, software assuring communication between the layers of the system, software for storage and archivization of measuring data, software managing the work of the system (configuration of the system, testing the system, the initialization of measuring sessions).

The introduced structure of the measuring system uses the newest solutions, both in hardware and software. The applied solutions easy extension of the system and including it for any diagnostic system.

The problems troubling the practice of applying methods of diagnosis (Fig. 4):

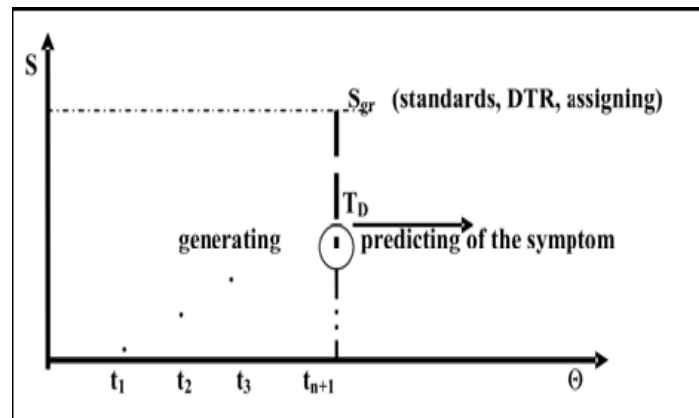1. The time of forming the diagnostic symptom.

Fig.4. System diagnostic actions

2. The change the boundary symptom - preventive system.

3. Complex state evaluation: the measurements of symptoms, reference to the boundary value, prognosis of the state, estimation of next diagnosing, the genesis of the cause of the measured symptom changes.

3. Diagnostic system of machine exploitation

Contemporary machines determined by such features as: functionality, reliability, availability, safety, mobility and flexibility of operation. Formation and maintenance of these features is possible with methods of technical diagnostics which enables:

- diagnostic construction and production of new machines and maintenance of machines in the condition of functional ability.

The use of the machines is characterized by:

- sets of randomly changing times of the correct work;
- randomly changing moments of the beginning and changing lengths of times of task duration;
- intensive work of people and machines in randomly changing period of exploitation time;
- the influence of randomly changing conditions of exploitation;
- various kinds of tasks executed in short periods of time.

The needs and conditions of market economy justify the necessity to introduce modern authorized strategy of the machine production and exploitation. In the proposition of this strategy, we do not lose the so-far accomplishments of the newest strategy of exploitation according to the state, but it is creatively modernized. The proposed strategy of exploitation – ASEM – indicates the creator and responsible for the product by name. The manufacturer interested in the quality and later the sale is responsible for the product from the very idea, through construction, production and exploitation, until utilization after the liquidation of the object.

The same manufacturer constructs and produces their products based on the newest achievements of technical thought, they protect their product with their own service during exploitation, and also they provide objects with diagnostic (preferably automatic) means.

The effectiveness of solutions in applying this strategy requires the improvement of: machine diagnostic models, the methods of diagnosing and prognosis of the machine state, economic, exact and reliable diagnostic equipment, the principles of the diagnostic vulnerability formation, the algorithms of conducting the maintenance of the machines in the ability state, methods of evaluating the efficiency of diagnosis and machine exploitation system. The specified questions embrace the whole problem and unambiguously establish the directions of the development of machine technical diagnostics.

The users of machines are interested particularly in their task ability, for determining which the following are necessary:
- determining the symptoms of ability state;
- determining the boundary values of ability state symptoms,
- determining the class of object ability,
- determining diagnosis periodicity.

The distinguished diagnostic tasks will be selectively discussed below, whilst their detailed description can be found in the author's works [6,7].

4. Boundary values of state symptoms

Task ability in the symptom notion is unambiguously described by the boundary value of the measured state symptoms.

Exceeding the boundary value means that the machine enters the state of accelerated wear characterized by high probability of a sudden breakdown.

Realized most often in the industrial practice passive and passive-active diagnostic experiments give state symptoms which are compared during concluding with boundary values available in many national, foreign, trade norms, or with data from own experience. When, however, there are no such norms for the examined machine, helpful can be the statistic description of a random exploitation process with the use of decay thickness or the frequency of the observed symptom occurrence.

Estimating the symptom boundary value for a safe shutdown of a machine before failure can be realized with the use of statistical methods.

The formula for determining S_{gr} minimizing the probability of failure, with the set, acceptable probability of redundant repair **A** can be written down in the form [1]:

$$P_g \cdot \int_{S_{gr}}^{\infty} \left(\frac{S}{X_g} \right) dS = A \qquad (2)$$

where: Pg - the ability probability.

According to Birger [1]: $A = k\,(1-Pg)$, where: k - the coefficient of the store (k = 1-3 for usual damages, k = 3-10 for dangerous damages), Pg - availability the machines determined from the dependence: $Pg = Nz\,/\,Nz + Nn$, where: Nz - the number of fit machines, Nn - number of unfit machines.

The row of simple transformations leads in the effect to the dependence:

$$S_{gr} = \bar{s} \pm \sigma_s \sqrt{\frac{P_g}{2A}} \qquad (3)$$

The received estimation of symptom boundary value based on the mean value, dispersion and repair politics, gives good basis for simple determination of boundary values of examined state measures in the industrial practice.

5. Diagnosis periodicity

The growth of intensity of the occurrence of damages along with wearing away the exploitation potential of the machine forces the need to optimize diagnosis periodicity. From the course damage intensity of the machine, it is concluded that that in the period of intensity growth it is necessary to increase the frequency of diagnosing.

This helps to reduce expenditures on the exploitation of the machine (the decrease: wear intensiveness, waste of the fuel, spare parts, material use), and at the same time the costs and time consumption, and the machine turn-off time grow.

The optimization of diagnostic periodicity comes down to two basic questions: how often to perform diagnosis?, in what range to perform the next diagnosis?.

There are several possibilities to determine diagnosing periodicity (the method of symptom boundary values, the methods of the smallest sum of exploitation costs), whilst for their realization indispensable are numerous statistical data, often troublesome (in the sense of amount and reliability) to obtain.

In this work, the question of diagnostic periodicity has been considered symptom notion, using a known symptom boundary value. Performing n-measurements of a chosen in a separate procedure signal measure (symptom), and determining on their basis a boundary value according to the dependence (2), there is a need to determine the date of the next diagnosing t_d. The essence of the method presented in the works [6,7] show that the date of next diagnosing is estimated from the dependence (Fig. 5):

$$t_d = \frac{(1-P_r)(S_{gr}-S_m)}{S_m}\,\theta_m \qquad (4)$$
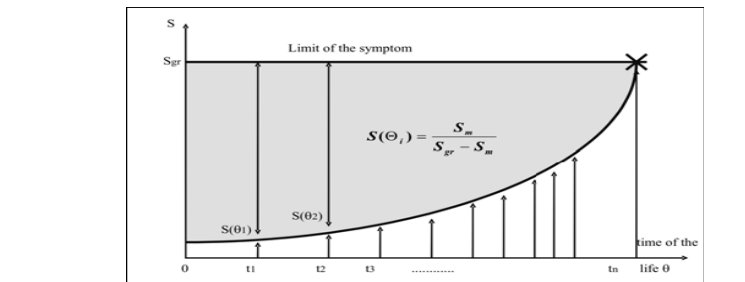

Fig.5. Periodicity of diagnosing in the symptom notion

6. Management of exploitation system

All of economic organizations have a certain system of management which fulfills its requirements within the realization of an accepted strategy. This is particularly essential for those which have a considerable influence on the course of production process (logistics, exploitation, tools and equipment), or control its fixed assets of considerable, from the point of view of the company, values (movement maintenance, repairs, check-ups) [4].

Subsystem functions:
- it conducts the classification and record of all fixed assets,
- it proposes basic technical-economic indexes,
- it supervises the exploitation of fixed assets,
- it analyses data from monitoring and makes decisions,
- it infers the liquidation of fixed assets,

- it plans, supervises and realizes all kinds of examination, maintenance and repairs,
- it establishes basic norms, records and accounts for performed works,
- it plans the supply of spare parts and necessary materials for repairs,
- it offers and motivates leasing, offers and motivates outsourcing,
- it organizes storage of spare parts, their distribution and accounting for,
- it plans investment tasks, organizes and realizes the purchase of machines and equipment,
- it organizes the receipt of fixed assets,
- it prepares the technologies of repairs.

Analyzing the range of functions attributed to the system for realization, it is possible to determine what groups of data ought to enter it, as well as what data it generates.

The model of exploitation system management was built on the basis analysis of two basic criteria, i.e. the flow and type of data, and functions realized by individual modules. The structure of exploitation system management, together with the flow of data, is shown in the fig. 6.
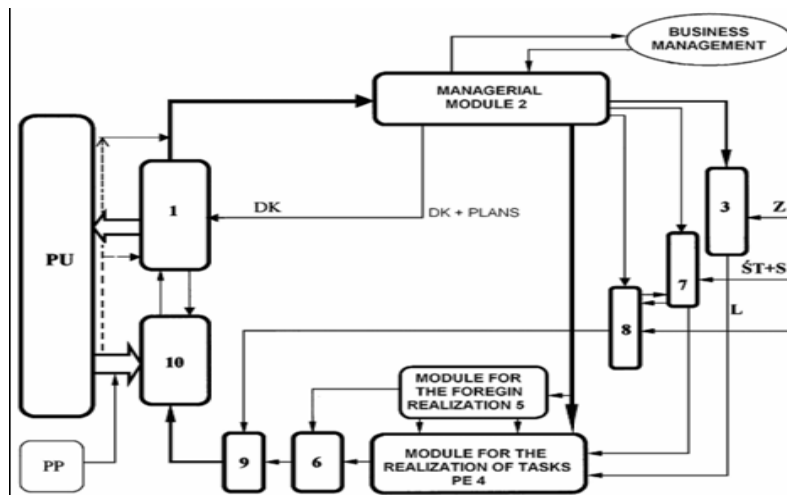

Fig.6. Model of exploitation system management

Separate modules creating the structure of the system realize the following functions:
1. The module of data processing is responsible for processing data sent to the system. Carriers and media of the transmission can be considerably diverse.
2. The managerial module, to which data of various degrees of aggregation enter from the module of data processing. It can be stated that about 80% of the data is processed according to the assigned algorithms, creating a basic set for the need of SE management.
3. The logistic module, which delivers indispensable materials, equipment, components and standardized machine elements for the needs of realized repairs; manages stock and analyses the level of stores, runs the record of distributed supplies, analyses their waste for individual orders, organizes and supervises transport of purchased technological equipment, co-operates with company's logistics in the range of the economy of scrap-iron.
4. The task realization module which realizes or supervises the realization of examinations and a bigger part of repairs.
5. The module of the strange realization, registering the range of repair works ordered to a third party.
6. The control module, checking the quality and range of realized works, outside and own.
7. The module of technical base renovation, purchase of machines, renovation and repairs.

8. The personnel training module, motivation and training of workers.
9. The accounting module, creates abstract summaries, as well as controls the needs for the realization of certain operations.
10. The technical module realizing the functions: planning, constructional, technological, technical state evaluations of the possessed equipment, record and updating, the emission of records.

PU - the exploitation subsystem which exploits machines and equipment.

PP - Remaining subsystems. Relations of these subsystems with the exploitation management system are defined to a smaller degree.

The construction of the model of the exploitation management system allows to identify the basic elements of its surroundings, as well as of the modules creating the subsystem itself.

7. Summary

The accomplishment of diagnostics in recent years using the achievements of many fields of science, allow treat it as a tool of formation and evaluation of machines, at all stages of their existence.

Looking at present trends of machine development it should be recognized that currently the growth of their quality is contained mainly in the sphere of automation. Automatic acquisition of measurable features is becoming the only objective way of evaluating and forming the quality of machines.

The range of investigations in the field of methodology of diagnostics includes such questions as: the source of diagnostic information, signals and diagnostic symptoms, the principles of detailed methods of diagnostics, modeling in diagnostics, diagnostic experiments, supporting diagnostics with modern computer technologies, diagnosing in systems of human engineering and social engineering, and the organizational and economic aspects of applying diagnostics. These question respectively apply to: source of information from the physical side and from the informative side, further bases of methods and investigative techniques, simulation and experimenting in diagnostics, and modern inference and visualization of worked out diagnostic-exploitation decisions.

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