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STRATEGIES IN DEDICATED DIAGNOSTIC SYSTEMS

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Abstract

So far the research on machine reliability has been done with the use of statistical methods on the basis of observed events. Now it is being replaced by computer simulation technology and programmed reliability tests. Requirements concerning the quality, marketing and logistics are radically changing the machine assessment criteria resulting in further, constantly growing, interest in the methods and means of technical diagnostics as well as computer technology involving the use of diagnostic procedures. Implemented procedures of the machine state identification are a basis of the Dedicated Diagnostic Systems. These systems enable determination of dedicated results of the procedures application effect in the field of the machine state assessment, its genesis and prognosis. It applies to any machine (with a given dynamics of its state degradation, with different diagnostic and process parameters, different environments and dynamics of value changes during operation) . Automation of the machine state assessment process requires elaboration of strategies for the dedicated diagnostic systems. In this study, special attention has been given to the strategy according to the machine technical state which involves making decisions according to a current assessment of the machine technical state. Another important strategy is based on economic efficiency as it is an indicator of the machine operation cost-effectiveness and provides basis for deciding on the machine withdrawal from use.

Keywords: *strategy of operation and maintenance, diagnostic system, diagnostic parameter, technical condition of machines*

1. Introduction

The methodology of the machine state identification process involves the following stages of assessment activities, in the below presented forms [3]:

a) diagnosis – process involving determination of the machine state in time Θ_b;
b) prognosis – process of involving prediction of the machine future states, allowing to, eg. schedule the next term of the machine servicing Θ_d ;
c) genesis - process involving tracing back the machine history, eg. in order to estimate the machine state in the past;

which provides the possibility of:

a) identification of the machine technical state in current time on the basis of results of diagnostic tests. This enables control of the state and localization of failure in case of the machine being out of service.
b) predicting the machine state in the future on the basis of incomplete history of diagnostic tests results. It allows to estimate the time of the machine reliable operation or the value of work to be performed by it in the future.

c) Defining the machine state in the past on the basis of incomplete history of diagnostic results which allows to estimate the machine state in the past.

Dedicated Diagnostic System consists of implemented procedures of the machine state identification, which enable [2]:

a) determination of an optimal set of diagnostic parameters and, on their basis, control of the machine state and localization of a failure, prognosis and genesis of the machine state,
b) establishing a test for an assessment of the machine state through:
   - determination of a relation matrix: value of diagnostic parameter – technical state (or time of the machine operation and maintenance),
   - establishing a control test for the machine state and localization of a failure;
c) prognosis of the machine state through:
   - determination of a method for the diagnostic parameter value prognosis according to the prognosis error function;
   - establishing a method for determination of the next servicing time;
   - determination of a method for the diagnostic parameter value genesis according to the function of error genesis,
   - estimation of the cause of machine damage found during testing.

Problems solved by procedures of the Dedicated Diagnostic Systems include:

- selection of the best diagnostic parameters describing the machine current state and analysis of their value changes during the machine operation.
- determination of a diagnostic test
- determination of the diagnostic parameter prognosis value $y_{jp}(\Theta_b + \tau_1)$ for prognosis horizon τ_1, by means of 'the best' prognosis method and scheduling the next servicing time Θ_0;
- determination of the diagnostic parameter genesis value $y_{jg}(\Theta_b + \tau_2)$ for genesis horizon τ_2 by means of 'the best' genesis method and determination of the machine cause of damage found during performance of the diagnostic test.

Once the procedures are triggered it is necessary to have the knowledge of data obtained from the machine experimental or static tests. These are:

a) set of the machine diagnostic parameters values $\{y_{jg}(\Theta_i)\}$ with the set of boundary values $\{y_{jg}\}$ and nominal values $\{y_{jn}\}$;
b) set of the machine diagnostic parameters values $\{y_n(\Theta_i)\}$;
c) and a set of the environment parameters values $\{y_k(\Theta_i)\}$;
d) set of the machine states $\{s_m(\Theta_i)\}$ recorded during operation .

Due to different diagnostic parameters which are to be determined for particular machines (automotive vehicle, working machine, assembly line, and others) the implemented DSD procedures determine, automatically and/or with the system operator's interference, appropriate (dedicated for each machine) methods in particular operating groups of DSD, that is, the machine state assessment, its genesis and prognosis. Thus, they provide a particular machine, with adequate, dedicated results of the procedures operation effects, such as:

a) set of diagnostic parameters dedicated for a machine
b) dedykowany dla maszyny zbiór parametrów diagnostycznych;
c) dedicated control test for the machine state and failure localization;
d) dedicated to the machine time of servicing
e) dedicated to the machine result of the failure cause estimation.

The DSD system should guarantee that the diagnostician will interfere with its operating only in case of:.

- change of the state diagnosis subject;
- change of the state diagnosis prognosis and genesis algorithm;
- removal of failures automatically detected within the system hardware and software.

The basic requirements to be met by DSD system are:

a) reliability;
b) high performance speed;
c) unification;
d) cost efficiency (low production and operation costs).

Moreover, the machine DSD system should provide:

a) simple, possibly optimal, algorithm of functioning;
b) universality, that is, possibilities of identification of states of different types of machines;
c) possibility of the state identification of high and low complexity machines ;
d) automatic generation of diagnosis;
   uniqueness and clarity of the presented diagnoses;
e) user friendliness.

2. Strategies of operation and maintenance in dedicated diagnostic systems

Automation of the system of the machine state evolution requires elaboration of strategies to be used in dedicated diagnostic systems. An operation strategy involves determination of methods for the machine use and maintenance and establishing relations between them in terms of the accepted criteria,

There can be distinguished following strategies[3]:

- according to economic efficiency,
- according to performer work,
- according to technical state,
- authorized strategy for machine operation and maintenance.

Strategy according to reliability

Operation and maintenance of machines according to this strategy involves making decisions on the basis of regular control of reliability level of different devices (various indexes of reliability), used until occurrence of a failure. Strategy according to reliability, also referred to as strategy according to failures, involves using the object until occurrence of a failure. There is no need to prove that this strategy can be used only when the consequences of failures do not violate rules of safety and do not increase costs of the machine operation and maintenance.

Strategy based on the input of work

Machines operating according to this strategy are limited by the amount of performed work which can be defined by the number of working hours, the amount of used fuel, the number of traveled kilometers, the number of work cycles etc. General rule of this strategy is to prevent failures (wear, aging) through servicing procedures within the defined limits of performed work, before a boundary wear level is reached. From the point of view of making use of the machine real potential this strategy is rather inefficient as the basis of acceptance of the permitted amount of work are extreme working conditions. The most unfavorable ones are accepted, such as: the weakest links (elements, parts) of the machine, extreme loads which may not always and not to the same extent be revealed during operation.

Authorized strategy of machine operation and maintenance

Qualitative changes forced by the market economy are of great importance in all fields of economy including the use of fixed assets. Needs and conditionings of the market economy justify the necessity of implementation of an authorized strategy of machines manufacture and operation. In the proposal of this strategy the so far existing achievements of the latest, state related operation and maintenance strategy, are not lost but creatively modified.

Special attention has been given to the strategy according to economic efficiency and the technical state. In the strategy according to economic efficiency the machine cost effectiveness is of key importance for the decision on the machine withdrawal from use. Results of economic efficiency can often lead to withdrawal from use of machines that are still serviceable though not efficient enough from the point of view of the user.

Proper application of this strategy needs a lot of statistical information from the field of financial management of the operation department, knowledge of decision models, measuring methods of values and economic efficiency indicators and optimization account.

Strategy based on the machine technical state involves making decisions on the basis of current assessment of technical state of the machines, their systems or elements and (fig.2.1).

It enables elimination of the most common defects connected with operation of machines according to other strategies.

The success of this strategy is connected with availability of simple and efficient diagnostic methods, preferably incorporated in the constructed machines which in turn are controlled by the system of the state monitoring.

Each automatic diagnostic system should be designed with regard to the costs caused by mistakes of alpha and beta type, and its decision strategies should be optimized in terms of global cost minimization expressed by the weighted sum of those costs. Error of alpha type, that is ‚false alarm', occurs when the system will not notice the object real deficiency due to insufficiently precise diagnostic procedure or wrong data. In radiolocation systems (which the names of errors come from) costs of a false alarm are measurable and equal to the price of an unnecessarily launched missile or dispatch of an squadron of airplanes. The costs of errors of beta type in these systems can be catastrophic, for instance because of bombing a high security object.

Generally, it can be said that for objects less complicated than vehicles, the errors of alpha and beta type involve costs of machines down time and unnecessary overhauls, whereas, errors of beta type can generate costs equal to the price of an object damaged during the failure or its replacement. Obviously, it is not possible to eliminate both types of errors at the same time, and reduction of frequency (probability) of one type of error occurrence usually involves a more frequent occurrence of the second type of error. Therefore, each technical solution needs to take into account the difference between costs of the two kinds of errors and be a compromise between technological capabilities, costs of operation and maintenance and the legislation requirements. Strategy of identification and signaling of failures in deck systems must account for the fact that symptoms of failures of the vehicle elements and subsystems can occur not only due to their wear or damage but also because of extreme and unnatural conditions of operation caused by the style of driving, quality of the road, low quality of fuel or its contamination, weather conditions, engine freezing or moistness, etc. Symptoms of failures recorded in such situations disappear along with disappearance of external causes. Because of this the diagnostic system should have a built-in mechanism of inactivation of failure situations caused by symptoms of this kind [3].

In order to be successful in implementing technical solutions of dedicated systems, manufacturers must focus on[1]:

- reduction to minimum, the probability of detection of errors of the type alpha and beta in control tests,
  activation of the module of failure signal as rarely as possible,
- self-turning off of a given module when the failure symptoms disappear,

- providing all the persons interested in repair and diagnosing an object with the most complete diagnostic information enabling easy identification of failures.

The operation principle of a decision strategy for vehicles (fig.2.2), which will further be called strategy of symptom confirmation SPS, can be specified in the following way. A system state is considered to be fit for use when in its controller memory there have been recorded no codes of errors. It can be obtained after a longer time of the object operation without occurrence of errors – after erasing diagnostic information recorded in the system by means of a proper reading apparatus or after resetting it.

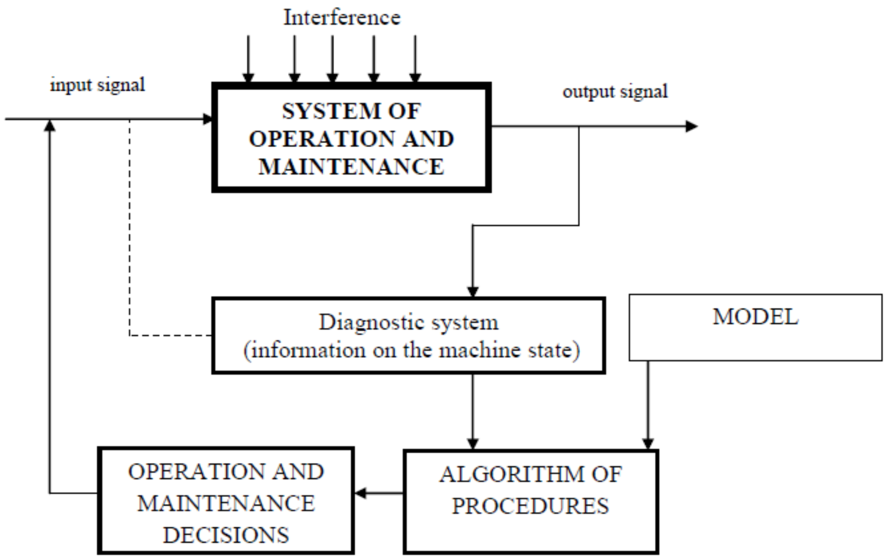

Fig.2 Diagnostic control of the system of machine operation and maintenance [3]

Once the first symptom of failure is discovered the system enters the state of first degree alert. Then a set of momentary parameters defining the object operation state, measured when the negative result occurs, the so called frozen frame', must be registered, also codes of errors whose symptoms have been discovered can be remembered as well. These codes, which will further be referred to as code of waiting errors (KO), have the same form as codes of recorded errors (KZ). KO codes, in literature named 'pending DTC', need to be distinguishable in the system from appropriate codes KZ.

The system goes from the state of first degree alert to the state of fitness for use if during 80 full cycles there have not been observed conditions similar to the ones recorded during occurrence of the first symptom. The system goes to second degree alert to fitness for use state after performing 40 cycles if there have occurred no failures.

Apart from the above described decision rule SPS, there has been used a strategy of statistical treatment of tests results which the most effective in eliminating errors of alpha type. Strategy which from now on be referred to as SOS, makes use of digital averaging with Exponentially Weighted Moving Average EWMA. Averaging of this type is a known method of elimination of big measurement deviations maintaining unchanged the mean value of measurement values series.

Digital algorithm of this averaging is used by the following equation[1]:

$$\overline{P_n} = P_n \cdot F + (1 - F)\overline{P}_{n-1} \tag{2.1}$$

where :

$\overline{P}_n$ -current mean value computed after n cycles

P_n -value of diagnostic parameter measured in the n-th cycle.

$\overline{P}_{n-1}$ - mean 'previous' value computed afer n-1 cycles.

F – a constant of filter.

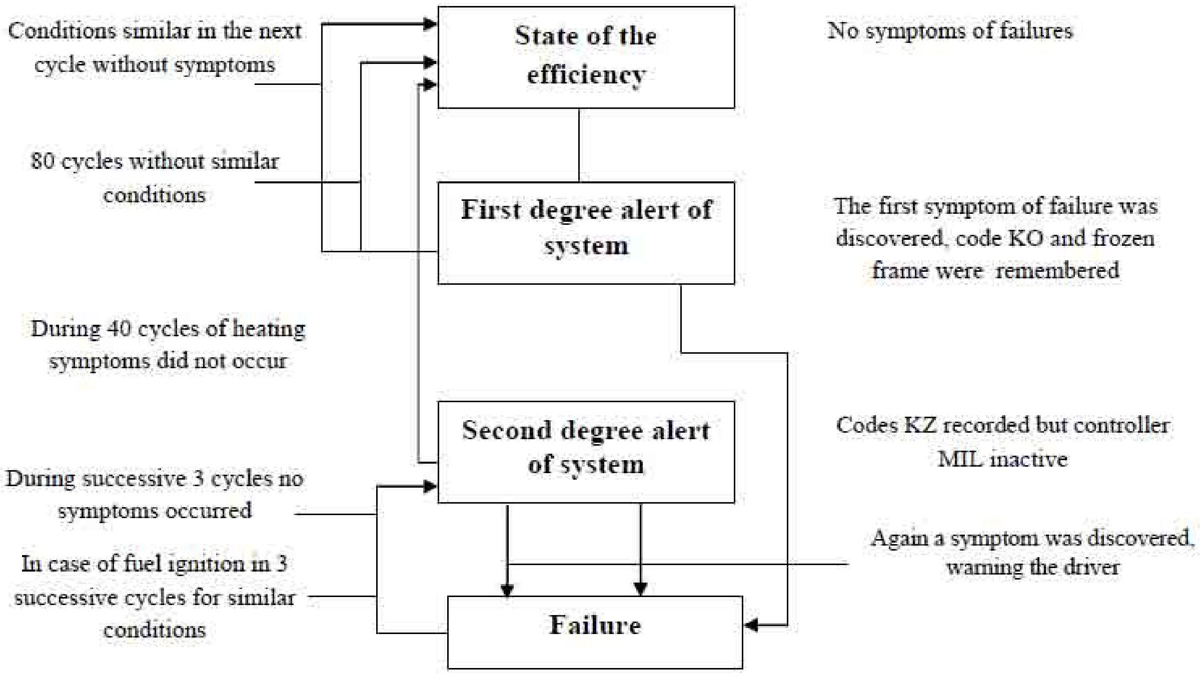

Fig.2.2.State of alert for dedicated diagnostic system [1]

As it is known, a digital filter with such properties is characterized by ex-potential response to a sequential change of the input value. Time constant (falling or rising) is defined by equation:

$$T = [1/F - 1] \times T_{\max} \tag{2.2}$$

where T_m is time of calculation of a diagnostic parameter usually equal to one cycle duration time length.

Whereas, the SOS procedure is used for identification of damage to elements which undergo gradual degradation rather than rapid failures and whose damage does not threaten other elements. This applies especially to failures of a catalytic reactor. The basic diagnostic parameter of such elements is their properly defined efficiency, expressed by analogue quantity.

3. Summary

Application of optimal methods for the machine technical state assessment in the process of operation and maintenance is the basis of the state identification process automation. This automation requires elaboration of a strategy for application of dedicated diagnostic systems. These systems enable : determination the optimal set of diagnostic parameters and according to them, control of the machine state and detection of a failure, prognosis and genesis of the machine state and determination of the machine state assessment test.

In this work there have been described rules of operation and maintenance strategies, with special emphasis on decision strategy, according to which once the first symptom of failure is detected the system enters the state of alert and strategy of statistical tests results treatment, which is fairly widespread.

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