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DETERMINATION OF DIAGNOSTIC ACTION INTERVALS FOR PLANNED INTERVAL MAINTENANCE

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ABSTRACT: Main aim of machine preventive maintenance is to prohibit the development and beginning relevant failures and so to hold life and durability of the machine on the prescribed level. For performing the effective maintenance of the machine it is necessary to know cause for that it comes to undesirable technical states and failures of the machine. The prevention plays a very important role in the maintenance process. It creates a base for effective maintenance. Another considerable factor is reliability. The check of machine geometrical accuracy is important also during machine use because it enables to disclose deteriorating technical condition that is shown in final consequence in manufacture of bad quality. In essence at all causes a human factor shares as an author of the failures origin. The modern maintenance methods RCM (Reliability Centred Maintenance) and TPM (Total Productive Maintenance) count with activity of the human factor as a man commits aware and unaware mistakes.
KEYWORDS: diagnostics, reliability, maintenance, technical diagnostics

INTRODUCTION

Initial frequency of diagnostics functions for the given object is determined on the basis of the service man experience. According to the first measurements at single functions the time course of the monitored diagnostics quantity or the parameter TD(t) (Figure 1) ascertained. Maximum increase of the parameter is compared with the critical value of the parameter. The critical value of the parameter corresponds to an important failure in our case. On the basis of this comparing the new frequency of diagnostics functions is determined so that probability of crossing the parameter of the relevant failure xp up to further function performing is 5 percent.

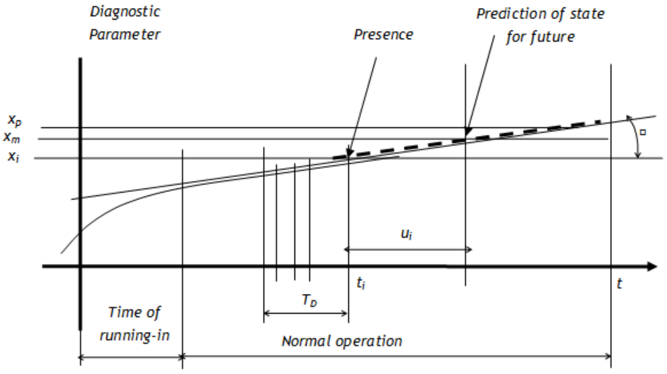

Figure 1. Example of wearing course in normal operation T_D - time interval in that diagnostics functions were performed, t_i - time of the last diagnostics function, x_p - critical state of parameter (important failure)

In the phase of running-in the wear is intense because produced areas that are in touch were not still adapted mutual. The contact of the areas is transmitted on unevenness peaks of surfaces roughness profile. This unevenness is by mutual effect plastically deformed or worn.

After the phase of running-in every part has still the so- called reserve on wear. This reserve is gradually exhausted and outwardly it is shown by limited function of the given mechanical nodal point. More functional surfaces can create the whole function of the nodal point in some cases. Then malfunction is shown by sum wear of all surfaces. The reserve is not given by intense of wear but allowed clearance of the mechanical nodal point. This clearance determines an important failure. In some cases then the relevant failure can be found still in normal phase of wear. In this case a forecast of optimum time for function of maintenance is simply computable. It is the linear dependence

$$u_i = \frac{x_m - x_i}{tg\alpha} \qquad (1)$$

$$tg\alpha = \frac{dx}{dt} \quad (2)$$

where: x_m- the state of the parameter after achievement it, it is necessary to perform maintenance (monitored failure), x_i - the measured state of the parameter on time t_i, u_i - the optimum time for maintenance performing.

It is necessary to perform a function of maintenance at ascertaining an important failure that is given by the value x_m.

PRECISION OF CALCULATION

Precision of calculation will depend from precision of determination of wear trend directions. We must have a record of one measurement at least in normal phase of operation. After the normal phase of operation the phase of intense deteriorating operation follows. In this phase the wear is more intense because of growing dynamic forces at increased clearances but it can be also because of material surface layer fatigue. It critical state of wear interferences up to this phase then the calculation of the optimum time for maintenance has more complicated character.

Frequency of diagnostics function: $$f_i = \frac{A}{(x_m - x_i)^B} \frac{dx}{dt}^C + D \quad (3)$$

Time interval of following diagnostics function: $$d_i = \frac{1}{f_i} \quad (4)$$

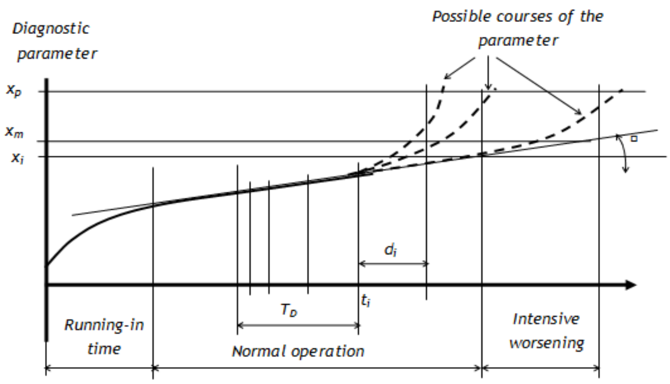

Figure 2. Example of typical course of wear

where: A, B, C, D - empiric, non-dimensional coefficients choice so that is 95% certainty that in this interval it does not come to the important failure.

The stated interval di on the basis of verified results can be further adapted according to following economical calculation:

$$k_d = \frac{n_d}{n_u + n_p} \quad (5)$$

where: nd - specific costs on application of diagnostics function; nu - specific costs on maintenance performed by correction of important failure; np – pecific costs on shutdown periods at correction of the important failure

If the coefficient k_d is larger than we can lengthen the interval di. We accept by it the higher risk that it comes to the important failure but the total costs on operation will be lower. If the coefficient k_d is smaller than we shorten the interval d_i. In the case k_d = 1 we do not change the interval d_i.

ECONOMICAL JUSTIFICATIONS OF MAINTENANCE AND TECHNICAL DIAGNOSTICS UTILIZATION

We meet in current life also with such reliable products that do not demand maintenance and diagnostics during all time of life if they are used by prescribed method. It is an ideal solution from the standpoint of the user but it is less such systems. The preventive maintenance also the diagnostics has mostly an important significance. For an estimate of maintenance use or technical diagnostics economical advantages we must know the reliability of the given product respectively system. In many cases it is very difficult to determine the reliability. There are following reasons:

- *The system reliability was not monitored till now then there are not statistical records,*
- *Determination of the system reliability is exacting on time and costs,*
- *Information about reliability are unavailable for public from commercial reason,*
- *The system reliability could not be verified because it goes about a new system,*

At economical evaluation it goes out often in practice from assumptions and experiences of experts only. Also this information has a high value and often is sufficient for putting suitable technical diagnostics and maintenance. Experiences from evolutionary works of product have an important significance. At design of product in essence we predestine preventive maintenance works for some parts e.g. lubrication of bearings and design of lubricating passages, oil gauge in gear box etc. Structural solution of these nodal points is such one that they enable the simplest performing maintenance works.

The reliability of object (product, manufacturing system) it is possible to judge from some standpoints practically in stage of its arising already. From this standpoint we classify the reliability as follows:

- *reliability of design (quality of design),*
- *reliability of working (quality of conformance),*
- *reliability in working.*

Economical access rests in essence in it that we determine the list of probable failures and we know to compute costs for their removing. Simultaneously we have available also the estimate of probability density for occurrence of single failures also other available information about reliability.

Costs connected with failure at current state of maintenance and diagnostics:

Ai – damage caused by failure of the i-part:

- *costs of correction or exchange of part.*
- *costs caused by shut-down period.*

Bi – probability number of failures during the determined period (choice of time depends on concrete case). Determination of period depends from our attitude during what time we want have secured profitability (returning) of inserted investments. It can be:

- *time of durability.*
- *time of service life.*
- *concrete time stated on basis of object moral growing old pace estimate.*

Costs connected with failure at proposed use of new maintenance and diagnostics.

- *Ui – costs on preventive maintenance of the element i*
- *Ci – probability number of failures during the stated period if new maintenance is used (Ci < Bi)*
- *Di – costs on use of technical diagnostics (installation, price)*
- *Ei – probability number of failures during stated period if new technical diagnostics is used (Ei < Bi)*

n – number of monitored parts that we decided to take into consideration

Economical advantage sets in after fulfilling the following unevenness:

$$\sum_{i=1}^{n} A_i B_i > \sum_{i=1}^{n} (A_i C_i + U_i) \quad (6)$$

For introducing the new technical diagnostics:

$$\sum_{i=1}^{n} A_i B_i > \sum_{i=1}^{n} (A_i E_i + D_i) \quad (7)$$

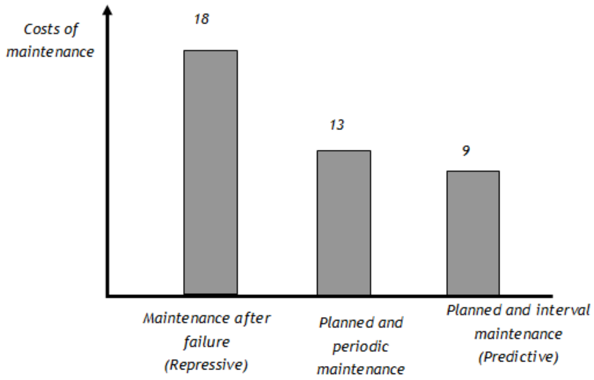

Figure 3. Cost saving on individual types of the maintenance

In the case that it goes about relevant systems where it is possible to come to endangering human lives or high material damages, the given system must have unconditionally secured protection by the maintenance also the diagnostics. In this case it is not question whether to use a protective system but it is the question which protective system has be used. The above-mentioned access to the economical solution is in strong measure depended from right information. In the first row the thorough analysis of possible failures must be made. It is possible to secure through expert experiences only.

The right determination of the coefficients B and C is the further problem. The coefficients are also dependent from human factor. If serious data about failures of the system are not available then it is possible to estimate these coefficients only. There are however the cases when also at Bi = 1 (one relevant failure during the stated period) it is sufficient on the economical introducing the new maintenance or the diagnostics.

DEVELOPMENT OF COSTS IN DEPENDENCE FROM TYPE OF THE MAINTENANCE

Modernization of the maintenance and introducing of diagnostics advances in large workings always pays. The following diagram documents the saving on simple types of the maintenance. Costs are expressed in relative numbers.

General criterion of total operational cost minimisation

The Figure 4 goes out from the assumption that with increase of the technical diagnostics level and the object maintenance the costs that would arise otherwise owing to damages caused through neglecting the diagnostics and the preventive maintenance go down. They are first of all the costs connected with restoration of the object and the costs arising at shutdown periods of machineries and at manufacturing systems also the costs connected with production of wasters on account of deteriorating technical state of manufacturing machinery.

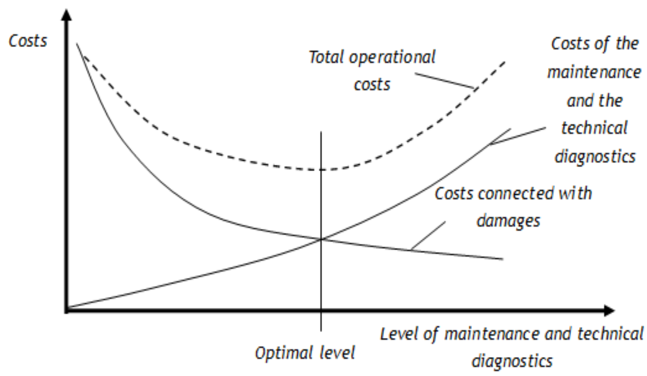

Figure 4. General criterion of total operational costs minimization

On the other hand increase of the maintenance level and the technical diagnostics raises the costs on securing object reliability. They are the costs connected with the price of works on maintenance, costs on operation, purchase and installation of the technical diagnostics also the costs connected with shutdown periods because of the maintenance. The total operation costs are the whole of all already mentioned costs referred to some longer time period e.g. year. The task of designers is to choose such a level of the maintenance and the technical diagnostics that the total operation costs will have minimum value.

Check of geometrical accuracy

Main check of geometrical accuracy of the manufacturing machine is performed at acceptance test already. The results ascertained at tests are a part of technical documentation of the machine and are available for the customer. The prescribed values of accuracy for single types of the machines are given by series of standards beginning from STN 20 0300. The check of machine geometrical accuracy is important also during machine use because it enables to disclose deteriorating technical condition that is shown in final consequence in manufacture of bad quality.

On basis of measured results it is possible to deduce also some causes of technical condition deteriorating. The geometrical accuracy resides in measurement of mutual deviations of shape, positions and dimensions of machine functional parts that participate on forming of resultant shape of work piece. It is e.g. directness of guide surfaces on bed; peripheral run- out of spindle came hollow axial movement of spindle etc.

CONCLUSIONS

In essence at all causes a human factor shares as an author of the failures origin. The modern maintenance methods RCM (Reliability Centred Maintenance) and TPM (Total Productive Maintenance) count with activity of the human factor as a man commits aware and unaware mistakes.

He is a fallible creature and then because of securing effectiveness and safety it is necessary to count with his failure. At the failures in some cases it is analysed also an intention of the man sharing on the failure origin.

During planning of maintenance it is necessary to create an effective system for scheduling of maintenance interventions in order to ensure a stable operation of machines and machinery. Said in other words: by means of the planned maintenance to keep machines in such state, which avoids unexpected breakdowns or idling.

The prevention plays a very important role in the maintenance process. It creates a base for effective maintenance. Another considerable factor is reliability. Reliable machine is working without a failure during required time interval. If we are talking about reliability, we are thinking about strategy, methodology and programs developed in order to optimise manufacturing systems. A global approach to the reliability integrates all the above-mentioned initiatives into one complex system, which is built on serious basic components.

Usually, it is possible to identify certain typical changes of machine or machinery parameters, which are occurring before a real failure appears, for example: uncommon intensity of mechanical vibration, higher temperature, increased noisiness, reduced tolerance of products, worsened lubrication, other appearances.

Taking into consideration all the presented facts it can be said that the technical diagnostics is a multi-parametric system and the diagnostic process has to be performed complexly. The technical diagnostics is a measuring process, which is based on monitoring of various physical characteristics during current operation, whereas any change of these parameters is a relevant indicator of an undesirable dynamic change inside of machine.

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