THE OPTIMAL PLAN OF PREVENTIVE MAINTENANCE OF THE ELECTROEROSION EQUIPMENT SODICK AQ15L

LUBOSLAV STRAKA, SLAVOMIRA HASOVA

Technical University of Kosice
Faculty of Manufacturing Technologies
Department of Manufacturing Processes Operation
Presov, Slovak Republic

DOI : 10.17973/MMSJ.2016_11_201671

e-mail: luboslav.straka@tuke.sk

The main aim of planning suitable maintenance interventions during operation of the technical equipment is to prevent a failure creation. Adequate maintenance of its individual elements can prevent the development of major failures, but also significantly increase the reliability and extend the service life. In general, the removal of a major failure of technical equipment is very much costly, but also time-consuming as carrying out the preventive maintenance at certain intervals. Therefore, these reasons compel us to deal with planned maintenance of technical equipment already in phase of design. However, the important question is determining an appropriate interval for preventive maintenance of the parts of technical equipment. The paper describes a procedure for optimal preventive maintenance for CNC electroerosion equipment Sodick AQ15L when considering Weibull distributions of random variables of failures.

KEYWORDS

preventive maintenance, lifetime, equipment, optimalization, Weibull distribution.

1 INTRODUCTION

Valid Slovak Technical Standard STN EN13306 defines the maintenance as the set of all the technical, administrative, and management actions for the required service life of technical equipment in order to the maintain or restore the situation in which the technical equipment can carry out under specified technical conditions the required functions. From the above definition, it follows that the aim of maintenance is ensuring operation of technical equipment for the required time, respectively, entire life in working order. The absence, or improper, or inadequate maintenance of technical equipment results in a decrease not only its reliability [Cacko 2014], but also a significant shortening of its service life. Occasionally, there are cases where the elimination of the consequences suffered a major failure of technical equipment is much more expensive, but also time lengthier, than perform the adequate preventive maintenance. Above reasons are forcing us to address the question of technical equipment not only during operation, but already at the stage of the design. At the same time the efforts of designers in the design of the technical equipment chosen arrangement of the various elements, respectively construction elements, so that the device as a whole may be operate as required without the failure, ideally for the guaranteed time. In practice, this effort is often limited to the actual technical level of the used structural elements [Dobransky 2013]. Therefore, in the phase of constructing is necessary to take account the requirements of maintainability with an emphasis on the overall arrangement of the various construction elements of technical equipment. Arrangement of the components, respectively, of the individual construction elements of technical equipment, should be such that any eventual failures can be easily removed in the shortest time, if it is possible. It follows that sustainability as a characteristic of reliability is very closely related to maintenance. It represents a complex of measures which aim to operate in all areas and phases of the application itself of technical equipment through its production to the decommissioning. It refers to the degree with which technical equipment can be returned after the failure from the state of failure down time to the state of trouble-free operation [Janacova 2015]. In addition to that it has on the efficiency of carried maintenance interventions significant impact the service of the process equipment, its subsequent operating mode [Salokyova 2016], used technical resources, and also the physical environment in which is the maintenance of technical equipment carried.

2 CLASSIFICATION OF FAILURES OF TECHNICAL EQUIPMENT

Any technical device cannot be constructed so that it will not appeared failures of different nature, sooner or later. These are either minor errors or failures fundamental character. Minor error has no significant impact on the reduction in loss of functionality or operability of technical equipment [Panda 2014]. It cannot be said about serious or emergency failure. Emergency failures of technical equipment can be characterized as a phenomenon which resulting in the loss of ability to perform a required function. Everyone, whether a minor error or emergency failure, has a reasons and also the consequences. Probability of occurrence of these failures is determined or influenced by random phenomena and factors, therefore, indicators of reliability have random nature. An important indicator of the reliability theory of technical equipment failure rate is a parameter λ (t) which is based on long experience and observation of failures in great detail describes the so-called "The Bathtub curve "(Fig. 1).

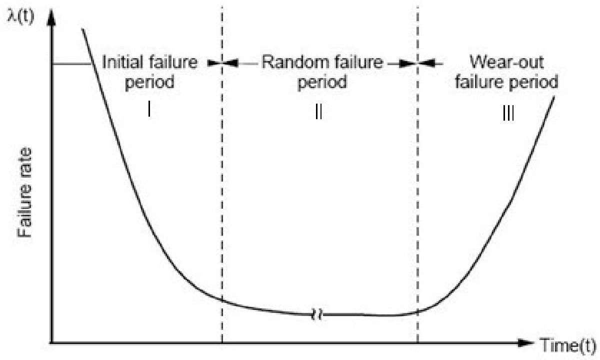

Figure 1. The Bathtub curve - describes the change in the intensity failures $\lambda(t)$ of technical equipment depending on the time of the operation *t*

Bathtub curve divides the time of technical life of equipment into three periods. The first period is characterized by an early failure due to faulty manufacturing, assembly, and storage. The second period is characterized by time of steady state operation in which failure occurs only sporadically. The third period is characterized by failures that are manifested by effect of wear, respectively aging of materials of individual components of technical equipment. From the above Bathtub curve in Fig. 1 it can be observed that the creation of failures of technical equipment is significantly influenced by irreversible processes, i. e. the process of wear and aging. These irreversible processes lead to the achievement of the ultimate condition in which it is not possible to use the other technical equipment. Besides the above mentioned irreversible processes, it has influence on the very course of failures of technical equipment the operating environment, operating system, service equipment, and so on. The main aim of the maintenance is as far as possible to eliminate the adverse effects of wear and aging of individual components of technical equipment for its overall technical serviceability and durability.

3 ELIMINATION POSSIBILITIES OF FAILURE CREATION OF TECHNICAL EQUIPMENT

As mentioned earlier, one suitable method for eliminating harmful effects of wear and aging of the components, respectively structural parts of the technical equipment, is preventive maintenance. [Straka 2016] In general, the maintenance is described as a combination of all activities aimed at the maintenance of technical installations in failure-free conditions. In terms of strategy, the implementation of maintenance is particularly important the preventive maintenance. Preventive maintenance is understood as maintenance carried out at predetermined time intervals (period) or according to set criteria. Its role is to prevent the occurrence of disturbances by eliminating degradation processes due to wear or aging of its individual elements [Ružbarský 2013]. At the same time with increasing requirements to optimize maintenance work carried out it is also important to mention the significant presence of predictive maintenance. Predictive maintenance is done on the basis of the forecast derived from the analysis and evaluation of important parameters of the degradation of the individual parts of technical equipment.

The plan for preventive maintenance of technical equipment has to consider the extent necessary with the given assumptions:

- time of using of technical equipment is on unlimited duration;
- technical equipment may be in serviceable, the limit, or in failure state, and its condition is known to us;
- technical equipment is up to the time of performing maintenance in uninterrupted working order;
- maintaining the intact, but also disturbed elements of technical equipment, i. e. restoring serviceable states, can be performed without delay at the time of failure;
- the time of to failure of technical equipment is a random variable, and it has technically identical equipment, the same probability distribution in which failure rate increases over time due to aging and wear of the individual elements.

4 THE BASIC STRATEGY FOR IMPLEMENTING THE MAINTENANCE INTERVENTIONS

Basic strategy for the implementation the maintenance interventions are based on the method of maintenance management for achieving the objectives of maintenance. It represents a set of rules under which are performed the various maintenance activities and under which are planned their time course. Under the valid Slovak technical standard STN EN 13306 there are a number of basic (preventive maintenance, planned maintenance, predetermined maintenance, maintenance based on condition, estimated maintenance, corrective maintenance) and derived types of maintenance (remote maintenance, delayed maintenance immediate maintenance, maintenance during operation, and maintenance of on-site, maintenance performed by the user). In terms of basic strategy, the implementation of maintenance work is important to choose the appropriate type of maintenance. It must also decide whether it is appropriate for a given technical equipment to apply the scheduled maintenance (preventive), an unscheduled maintenance (corrective, after a failure) or maintenance based on diagnostics [Straka 2013].

Strategy for carrying out the maintenance of technical equipment can be divided into three categories:

1. Maintenance after failure which is aimed at eliminating minor errors or defects and restoring serviceable condition of technical equipment. This method of carrying out the maintenance should be applied only in the design node devices in which failure does not result in serious, or emergency failure, or major material damage of technical equipment.
2. Maintenance according to the schedule, which is based on mathematical calculations and determining the optimal plan for each maintenance interventions. This type of scheduled maintenance makes it very efficiently and effectively to prevent unwanted downtime fault whose consequences are emergency conditions of equipment or large material damage. It can be carried out at fixed regular or irregular time intervals or according to predetermined criteria.
3. Maintenance according to actual found situation tries to get closer to the ideal strategy model of performed maintenance interventions on technical equipment. With this concept, the maintenance of individual construction elements of the technical equipment is made on the basis of technical diagnostics and monitoring. [Tóthová 2015] Relevantly obtained diagnostic signals are diagnosed technical equipment which will assess the current technical status and decide on further steps, it means the need to maintain or not. By this strategy, the implementation of maintenance interventions, the individual elements of the construction elements, or the entire structural units are exchanged only when the diagnostic signals show the limit level of wear or degradation of material.

In connection with increasing requirements on optimizing the implementation of various maintenance interventions of technical equipment it is important to highlight the important position of predictive maintenance which is carried out on the basis of forecasts derived from the analysis and evaluation of important parameters of the degradation of the equipment. However, the highest level in accessing technical equipment maintenance work is the application of proactive maintenance. It encompasses preventive, but also predictive maintenance operations. The role of proactive maintenance is recovery planning, decommissioning planning, and determining the conditions of monitoring the state of technical equipment. It is therefore a strategy that uses corrective measures to prevent the formation of defects on the basis of their consequences. These corrective actions are focused on resources of emergency failures. It also deals with a detail view of emergency failures of technical equipment, it focuses on their symptoms and causes. The basis for proactive maintenance reliability is aimed at a systematic method of testing the productivity of technical equipment and the implementation of corrective measures to reduce the overall costs over their entire technical life. From the above it is evident that the periodic preventive maintenance is less effective than proactive maintenance which respects for the use of technical equipment. The following Tab. 1 provides an overview of the various strategies for maintenance of technical equipment showing, their advantages, disadvantages, and practical use.

Table 1. The basic strategy maintenance interventions carried out on technical equipment

Maintenance type	Advantages	Disadvantages	Field of use
The corrective (after a failure)	- Maximum use of the various elements of technical equipment, - No or minimal costs of a monitoring system.	- higher costs associated with the preparation and replacement of structural parts of technical equipment, - the need of replacement components in case of the unexpected failure	Suitable for easy and relatively inexpensive technical equipment for which there is no risk of emergency failure.
Preventive (according to plan)	- Technical equipment lifetime can be extended. - Time repair of technical equipment can be properly planned.	- Higher costs associated with too frequent exchange of structural parts of technical equipment. - Frequent downtime of technical equipment increases its running costs.	Suitable for most of technical equipment.
Predictive (according to the technical state of equipment)	- Knowledge of the current condition of the equipment. - Maintenance can be planned according to the current state of the art equipment. - Failure of technical equipment is well identified and repair becomes easier and faster.	- High acquisition costs for sensors and instruments of diagnostic signals. - Higher operating costs associated with maintenance of diagnostic system.	Suitable for complicated and relatively expensive technical equipment.
Proactive	- Knowledge of the current status of equipment. - Failure of technical equipment can be predicted on the basis of reliability model.	- High acquisition costs for sensors and instruments of diagnostic signals. - Low accuracy of prognostic and reliability model.	Suitable for technical equipment for which are at risk of failure, which is fatal (major material damage, loss of life).

On the following Fig. 2 can be observed a significant impact proactive and preventive maintenance of the operability technical equipment in the III. the period of their total technical life. [Fabian 2008]

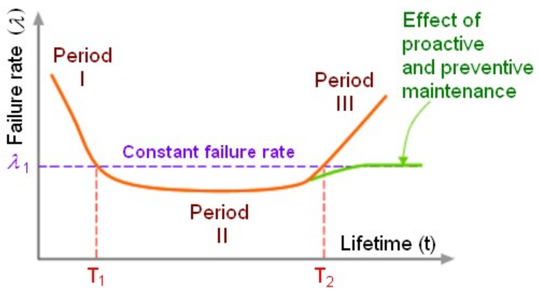

Figure 2. Influence of proactive and preventive maintenance for serviceability and the overall life of technical equipment

By including suitable proactive or preventive maintenance of technical equipment during its operation it can be significantly reduced the risk of emergency failures and also significantly extend their service life.

5 OPTIMIZATION OF THE PREVENTIVE MAINTENANCE OF TECHNICAL EQUIPMENT

As mentioned at the outset, there are now more often placed greater demands on the optimization of the preventive maintenance of technical installations. Although the determination of maintenance interventions on the current state of the art equipment, evaluation of diagnostic signals is much more effective in practical terms, this type of maintenance cannot be effectively applied in all of technical equipment. For majority of technical equipment is sufficient the preventative maintenance which is determined, on the basis of precise development of an optimal plan. This plan is based on a database of reliability indicators of particular technical equipment. Whereas the reliability indicators have probabilistic nature, it can be analysed by using continuous and discrete random variables, parameters, and statistical probability distribution. For maintenance of indicators is used much smaller number of statistical distribution than for analysis of indicators of reliability. The most commonly used statistical distribution in the theory of maintenance is normal, logarithmic - normal, exponential and Weibull.

Basic indicators, which characterize in detail the maintenance of technical equipment, are analogous parameters generally applicable in the theory of reliability. The main difference lies only in their interpretation. For example parameter *t* – time to failure is in theory of maintenance interpreted as parameter *t* - the time required to restore the serviceability of the equipment, λ - parameter of failure rate as parameter μ - intensity of repairs, and parameter *F(t)* - the probability of failure in time *t*, or $P(T \leq t)$ as parameter *M(t)* - the probability of successful completion of the repairs in time *t*, or $P(T \leq t)$.

As shown in Fig. 3 one of the indicators of partial characteristics of reliability, respectively sustainability can be expressed as two-parametric, as the length of time *T (h)* necessary to remove the emergency failures of technical equipment, or as the probability *P(t)* of recovery serviceability of technical equipment for a specified period of time *T(h)* following the moment of emergency failure. [Fabian 2008]

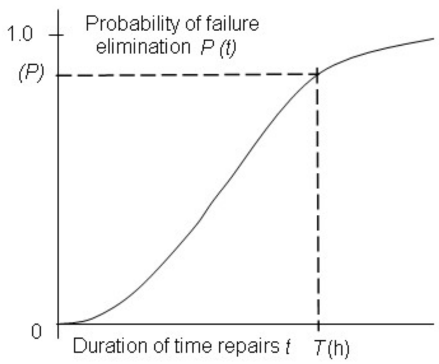

Figure 3. Dependence of probability of failure elimination *P(t)* of technical equipment depending on the duration of time repairs *T(h)*

The basic approaches used for optimizing the preventive maintenance of technical equipment are to determine the appropriate optimization criteria. Quite often used optimization criterion in the theory of reliability in the determination of optimal preventive maintenance schedules is the economic efficiency of fault-free operation of technical equipment. Its principle is based on an analysis of life-cycle costs of technical equipment, to investigate the impact of of maintenance applied to the total lifecycle costs. Input parameters of this analysis are costs associated with the acquisition of technical equipment and costs necessary to restore serviceability of equipment, removing emergency faults of the individual construction elements. In determining the optimal preventive maintenance schedules by using the theory of reliability is required for fault-free operation of technical equipment to determine appropriate timing of the execution of necessary maintenance interventions. These time points maintenance interventions of individual components, respectively construction elements of technical equipment is also necessary to choose, so that the maintenance carries out to ensure the achievement of the minimum average unit costs of serviceability condition throughout its technical life.

The input data for determining the optimal intervals of preventive maintenance of technical equipment are:

a) the total financial costs of carrying out preventive maintenance of technical equipment *Nu*;

b) the total financial loss *Ns* caused by an emergency failures of technical equipment. In general, representing the difference of costs incurred for maintenance after failure of the *Np* and the cost of preventive maintenance of technical equipment *Nu*:

$$Ns = Np - Nu; \tag{1}$$

c) the probability of emergency failure, depending on the interval of preventive maintenance $F(t_p)$;

d) functional dependence of the central interval of preventive maintenance on simple preventive maintenance interval $\bar{t}(t_p)$;

e) functional dependences of median cumulative costs incurred to ensure failure-free operation of technical equipment, caused by increasing wear of monitored elements, respectively construction elements depending on the interval of preventive maintenance $N_{Pu}(t_p)$;

f) functional dependences of median cumulative costs, incurred to ensure failure operation of technical equipment, established on the basis of diagnosis, depending on the interval of preventive maintenance $N_{Pd}(t_p)$.

Based on the cost of opposite trends in their unit expression is possible to determine the searched the optimum interval values of preventive maintenance by equation (2) for calculating the average unit cost [Fabian 2008]:

$$u(t_p) = \frac{N_u + N_s \cdot F(t_p) + N_{Pu}(t_p) + N_{Pd}(t_p)}{\bar{t}(t_p)} \ . \tag{2}$$

Functional dependence of the central interval, respectively the mean time of operation to preventive maintenance on simple interval for preventive maintenance $\bar{t}(t_p)$, can be determined from experimental data obtained by the equation (3):

$$\bar{t}(t_p) = \frac{1}{n}\left[\sum_{i=1}^{m(t_p)} t_i(t_p) + \sum_{j=1}^{n-m(t_p)} t_j(t_p)\right] , \tag{3}$$

where:

$t_i(t_p)$ - is operation timeo *f* the i-th element of technical equipment that is functional in the state t_p;

$t_j(t_p)$ - is operation time of the i-th element of technical equipment that is in the state t_p functionless;

$m(t_p)$ – is the number of elements of the technical equipment which is functional in the state t_p;

n - is the number of monitored elements of technical equipment of the same type.

5.1 An empirical determination of optimal preventive maintenance schedules of CNC electro equipment Sodick AQ15L In considering of the Weibull distribution of the random variable

When an empirical determination of optimal preventive maintenance schedules of individual construction elements of CNC electroerosion equipment Sodick AQ15L (Fig. 4) is based on the assumption that there is a real opportunity to experimentally monitor the technical equipment in the two-state model. At the same time there is a presumption that the technical equipment is available continuously to diagnose and based on the evaluation of diagnostic signals to establish the respective values of each reliability indicators.

Due to the large elements system of the technical equipment was intended in the design of optimal preventive maintenance plan only with failures which occur in the electroerosion equipment Sodick AQ15L most frequently in the design node of the mechanical movement of the tool and the workpiece, in the cooling system, in the distribution of dielectric fluid, and in the control system.

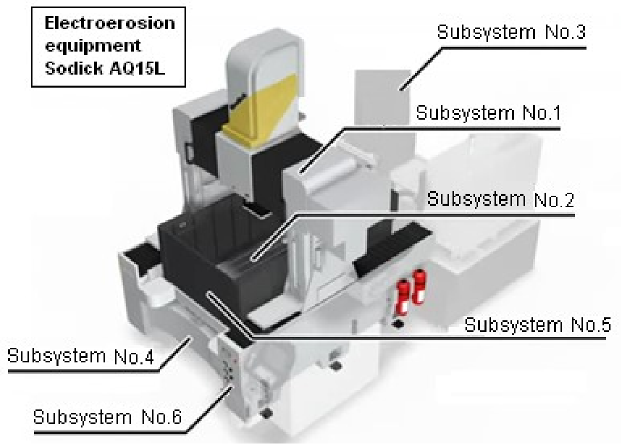

Figure 4. The basic structural parts of considered CNC electroerosion equipment Sodick AQ15L

Fig. 5 shows graphically the limit states, respectively emergency failure of the main construction elements (subsystems), of considered CNC electroerosion equipment Sodick AQ15L, whereby their coordinates are determined by relevant diagnostic parameters during its technical life.

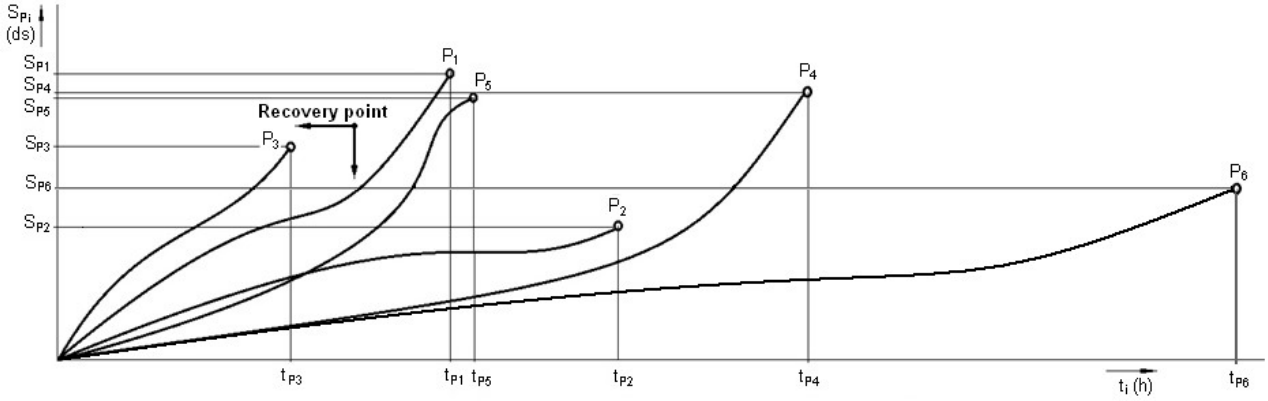

Figure 5. Dependence of diagnostic signals S_{Pi} of individual subsystems CNC electroerosion equipment Sodick AQ15L on operation time t_i

Curve No. 1 characterizes the diagnostic signal of tool electrode movement- subsystem S_{P1}; curve No. 2 characterizes the diagnostic signal of mechanical movement of the workpiece - subsystem S_{P2}; curve No. 3 characterizes the diagnostic signal of dielectric fluid filtration device - subsystem S_{P3}, curve No. 4 characterizes the diagnostic signal of dielectric fluid cooling equipment - subsystem S_{P4}, curve No. 5 characterizes the diagnostic signal of distribution equipment of dielectric fluid - subsystem S_{P5}, and curve No. 6 characterizes the diagnostic signal of control system equipment - subsystem S_{P6}.

The technical life of the individual construction elements of CNC electroerosion equipment Sodick AQ15L and diagnostic signal are random variables. Along with the probability density of time to the failure $f_1(t)$, $f_2(t)$, ...$f_n(t)$; distribution function $F_1(t)$, $F_2(t)$, ...$F_n(t)$; probability of trouble-free operation $R_1(t)$, $R_2(t)$, ... $R_n(t)$ and failure rate $\lambda_1(t)$, $\lambda_2(t)$, ... $\lambda_n(t)$ characterize the behaviour of the technical equipment during real operation. In determining the optimal preventive maintenance schedules we assume that the recovery will be carried out either at the moment of failure, or within a specified period during trouble-free operation of electroerosion equipment t_{Pi}, or in achieving the limit value of diagnostic signal S_{Pi} depending on which event occurs first. The t_{Pi} indicates the interval for recovery and S_{Pi} diagnostic signal of recovery. The optimized values of parameters t_{Pi}, respectively S_{Pi} depend on the economic and operating conditions of the element, and thus may vary. Preventive maintenance plan of considered CNC electroerosion equipment Sodick AQ15L considers the regenerative maintenance with the broken, but also with unbroken element. There are also known to average maintenance costs of broken N_p and unbroken elements N_u, as well as dimensions of parameter β and parameters of shape m of Weibull distribution of random variable with the probability of failure p. One approach to establish the normalized optimum maintenance interval of individual elements (subsystems) of CNC electroerosion equipment Sodick AQ15L is based on the proportion of medium costs c and shape parameter m by the graph in Fig. 6, while the share of medium cost is calculated by the formula (4) [Fabian 2008]:

$$c = \frac{N_p}{N_u} \tag{4}$$

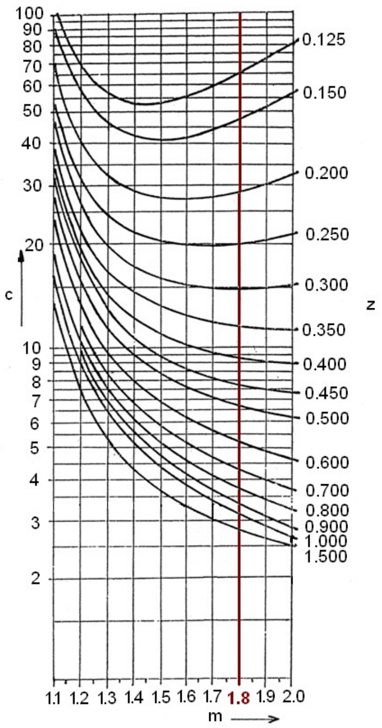

Figure 6. Dependence of the standardization optimal maintenance interval of individual parts of technical equipment z on the value of medium costs c and shape parameter m

Mean time to failure of operation MTTF of individual parts (subsystems) CNC electroerosion equipment Sodick AQ15L is calculated by equation (5): $MTTF = \beta \cdot \Gamma\left|1+\frac{1}{m}\right|$, (5)

While the gamma function $\Gamma\left|1+\frac{1}{m}\right|$ is determined from Tab. 2 based on parameter of shape m and probability of failure creation p.

Table 2. The values of the gamma function $\Gamma\left|1+\frac{1}{m}\right|$

Shape parameter	***Probability of failure creation p***								
m	**0.00**	**0.01**	**0.02**	**0.03**	**....**	**0.06**	**0.07**	**0.08**	**0.09**
1.6	0.8966	0.8961	0.8956	0.8951	....	0.8938	0.8934	0.8930	0.8926
1.7	0.8922	0.8919	0.8916	0.8912	....	0.8903	0.8901	0.8898	0.8895
1.8	0.8893	**0.8891**	0.8888	0.8886	....	0.8880	0.8878	0.8877	0.8875
1.9	0.8874	0.8872	0.8871	0.8869	....	0.8866	0.8865	0.8964	0.8863
2.0	0.8862	0.8861	0.8861	0.8860		0.8858	0.8858	0.8858	0.8857

Table 3. Optimum preventative maintenance interval of individual construction nodes (subsystem) of CNC electroerosion equipment Sodick AQ15L

Construction node	Medium maintenance costs		The share medium costs *c*	Parameter of dimension β	MTTF	*z*	Optimum maintenance interval u_x [h]
	Damaged element *Np* [€]	Undamaged element *Nu* [€]					
Subsystem No. 1 *(mechanism for moving the tool electrode)*	2,000	350	5.7	15,000	13,337	0.55	7,335
Subsystem No. 2 *(mechanism for moving the workpiece)*	1,500	200	7.5	20,000	17,782	0.45	8,002
Subsystem No. 3 *(dielectric fluid filtration equipment)*	1,450	450	3.2	5,000	4,446	0.95	4,224
Subsystem No. 4 *(cooling equipment of dielectric fluid)*	1,800	500	3.6	12,000	10,670	0.80	8,536
Subsystem No. 5 *(equipment for distribution of dielectrics)*	1,600	300	5.3	14,000	12,447	0.60	7,468
Subsystem No. 6 *(control system equipment)*	900	300	3.0	18,000	16,004	1.10	17,604

Optimum maintenance interval $u=u^x$ of individual parts (subsystems) CNC electroerosion device Sodick AQ15L is calculated by equation (6): $u^x = z \cdot MTTF$ (6)
Tab. 3 provides an overview of individual parameters of optimal preventive maintenance schedules of individual parts (subsystems) CNC electroerosion equipment Sodick AQ15L. Based on the database of failure rate of individual construction elements (subsystems) of CNC electroerosion equipment Sodick AQ15L was calculated the optimum preventative maintenance interval when considering the Weibull distribution of time to failure. The optimal maintenance interval of the construction elements is within the range of 4,224 h for the subsystem No.3, i. e. filtration equipment of dielectric fluid, up to 17,604 h at subsystem No.6, i. e. control system equipment. The following graph in Fig. 7 shows the frequency of each maintenance interventions according to the optimum schedule of preventive maintenance and maintenance of damaged construction elements (subsystems) of CNC electroerosion equipment Sodick AQ15L during the considered technical life 50,000 h.

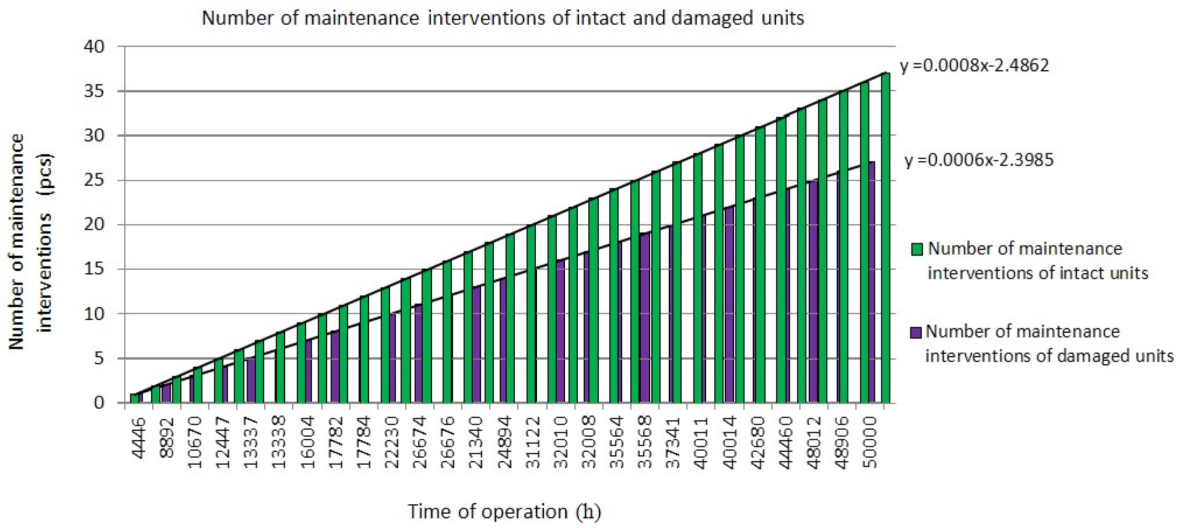

Figure 7. Graphical representation of the number of individual maintenance interventions respecting the optimum interval for preventive maintenance and maintenance interventions of damaged construction elements (subsystems) CNC electroerosion equipment Sodick AQ15L

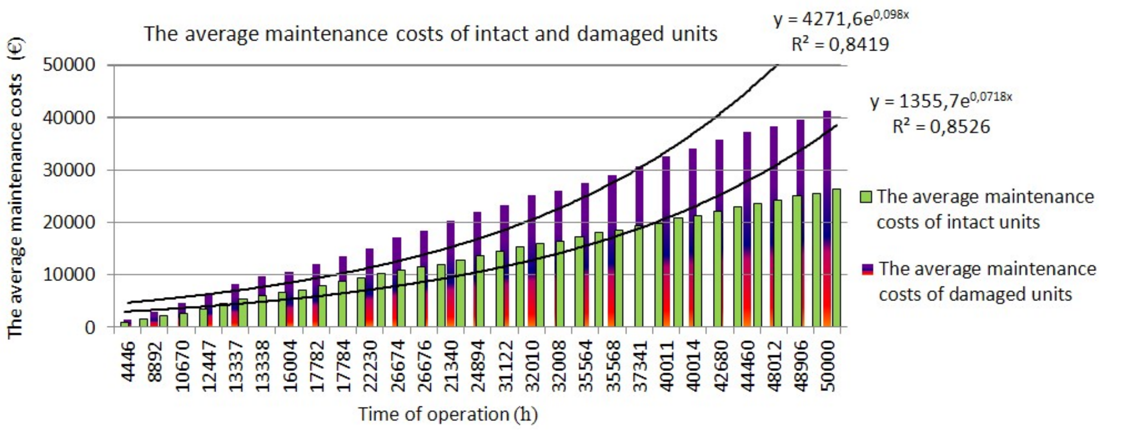

Figure 8. Graphical representation of the average costs incurred for the maintenance of damaged and intact construction elements (subsystems) of CNC electroerosion equipment Sodick AQ15L

From the graph of Fig. 7 it is clear that the first failure of CNC electroerosion equipment Sodick AQ15L should happen after about 4,446 h, if it does not execute preventive maintenance at the time of 4,224 h from system start-up to subsystem No. 3, i. e. of filtration equipment of dielectric fluid. By comparing the number of individual maintenance interventions of damaged and intact construction elements (subsystems) of the equipment it can be observed slightly higher frequency of planned preventive maintenance. It is overall of more than 10 maintenance interventions when considering the service life of about 50,000 h of electroerosion equipment.

The graph on the following Fig. 8 shows the average costs of maintenance of damaged and intact elements (subsystems) of CNC electroerosion equipment Sodick AQ15L during the considered technical life of the equipment for 50,000 h.

From the graph of Fig. 8 it can be observed significant difference in the increase of the average costs incurred for the maintenance of damaged and intact elements (subsystems) of CNC electroerosion equipment Sodick AQ15L during the considered technical life of the equipment for 50,000 h. Total average costs of optimal preventive maintenance schedule in time of 50,000 h of operation is about 13,000 € and for the maintenance of damaged elements at about 41,000 €, difference in the total amount is 28,000 €.

6 CONCLUSIONS

The probability of emergency failure of CNC electroerosion equipment Sodick AQ15L can be within the first hours of operation higher due to manufacturing or installation errors/failures. After this initial period, follows the period called steady state operation. During this period, the probability of failure for a longer period is relatively low. Crucially, position for maintaining serviceability of technical equipment during this period as long as possible is preventive maintenance equipment. The aim of scheduled preventive maintenance is through appropriate maintenance interventions, for example cleaning of individual parts, lubrication, replacing of worn parts, to maintain the reliability the indicators at the required level, and thus to increase overall service life of technical equipment. A necessary precondition of efficiency and effectiveness of preventive maintenance is that the cost of its implementation does not exceed the cost of removing emergency failure. This is necessary to have developed precise plan of optimal preventive maintenance. The optimal maintenance interventions schedule of technical equipment must be chosen according to the power parameter which characterizes the progress of wear or degradation of the materials of its individual parts. The base for optimization of preventive maintenance is the database of data on time of operation of the individual construction elements (subsystems) of technical equipment to their physical limit state, i. e. to the stage where the design node completely loses the ability to perform a required function, for example, due to wear, aging, corrosion, and so on. The paper aimed to describe the design of optimal preventive maintenance schedules of selected construction elements of CNC electroerosion equipment Sodick AQ15L. It was found that the preventive maintenance will not be carried out by determining the optimal plan, the first failure of considered electroerosion equipment Sodick AQ15L will occur at about 4,446 h from the time of its commissioning. Also under consideration was a difference of costs incurred for preventive maintenance in comparison to the cost of emergency condition removal of individual construction elements of technical equipment, including an assessment of the frequency of each maintenance interventions of damaged and intact structural nodes. It has been detected the minimum difference in the number of maintenance interventions of damaged and intact constructional node of electroerosion equipment Sodick AQ15L. Conversely, significant difference was in the total amount of costs incurred for the maintenance of damaged and intact construction elements considered technical equipment.

ACKNOWLEDGMENTS

The research work is supported by the VEGA Grants No. 1/0409/13; No. 1/0381/15 and by the KEGA Grant No. 027TUKE-4/2014.

REFERENCES

[Cacko 2014] Cacko, P., Krenicky, T. Impact of lubrication interval to operating status of bearing. Applied Mechanics and Materials, 2014, Vol. 616, pp. 151-158. ISSN 1660-9336

[Dobransky 2013] Dobransky, J., Mikus, R. and Ruzbarsky, J. Comparison of cooling variants by simulation software. Advanced Materials Research, 2013, Vol. 801, pp. 75-80. ISSN 1022-6680

[Fabian 2008] Fabian, S., Straka, L. Operation of production system.TU Kosice, 2008,252 p.,ISBN 9788080739898

[Janacova 2015] Janacova, D., Charvatova, H., Mokrejs, P., Vasek, V., Liska, O. and Pitel, J. The mathematical modeling of bound component extraction. International Journal of Mathematical Models and Methods in Applied Sciences, 2015, Vol. 9, pp. 91-98. ISSN 1998-0140

[Panda 2014] Panda, A., Prislupcak, M. and Pandova, I. Progressive technology diagnostic and factors affecting to machinability. Applied Mechanics and Materials, Vol. 616, pp. 183-190. ISSN 1660-9336

[Ruzbarsky 2013] Ruzbarsky, J., Zarnovsky, J. Optimization of parameters in the compression moulding process of thermoset products. Advanced Materials Research, 2013, Vol. 801, p. 61-66, ISSN 1022-6680

[Salokyova 2016] Salokyova, S., Krenicky, T. Analysis of the effects of factors in relation to vibration of technological head during the splitting of construction steels through hydro-abrasive splitting. Key Engineering Materials, 2016, Vol. 669, pp. 216-219, ISSN 1013-9826

[Straka 2016] Straka, L., Gerkova, J. and Hasova, S. Proposal of Preventive Maintenance Plan of Experimental Equipment. Key Engineering Materials, 2016, Vol. 669, pp. 523-531, ISSN 1013-9826

[Straka 2013] Straka, L., Corny, I. and Krehel, R. Evaluation of capability of measuring device on the basis of diagnostics. Applied Mechanics and Materials, 2013, Vol. 308, p. 69-74, ISSN 1660-9336

[Tothova 2015] Tothova, M., Balara, M. and Dubjak, J. Simulation model of cascade control of the heating system. International Journal of Engineering Research in Africa, Vol.18 pp.20-27. ISSN 1663-3571

CONTACTS:

Assoc. prof. Luboslav Straka, PhD.
Ing. Slavomira Hasova
Technical University of Kosice
Faculty of Manufacturing Technologies
Department of Manufacturing Processes Operation
Sturova 31, 080 01 Presov, Slovak Republic
tel.:+421 55 602 6346
e-mail: luboslav.straka@tuke.sk
e-mail: slavomira.hasova@tuke.sk