RESEARCH ON CHARACTERISTICS OF FAILURES FLOW ACCORDING TO THE MAINTENANCE AND REPAIR STRATEGY

Prof. PhD M. Mihov - Institute of Soil Science, Agricultural Technology and Plant Protection "Nikola Pushkarov", Sofia, Bulgaria
Email: M.Mihov@abv.bg

Summary: *In the practice of repairing the machines in agriculture, the following strategies are mainly applied: forced repairs; conducting repairs in plan order and a combined strategy with elements of both strategies.*
An investigation was carried out and analytical dependencies were obtained to determine the function of the recovery (characteristic of the failure flow) of the machine components in the forced repairs (after failure), to carry out repairs in a planned order and a combined strategy with elements of the first two strategies to calculate the required pool of spare parts to maintain machine performance.
KEYWORDS: *MAINTENANCE, REPAIR, FAILOVER FLOW CHARACTERISTIC, MATHEMATICAL MODEL, PREDICTION, MACHINE, ELEMENTS*

General conditions

The maintenance and repair system is a complex of organizational and technical events for servicing and repairing the machines. Includes planning, preparation, maintenance and repair in a consistent sequence and periodicity. It implements to provide for :

- Maintaining machines in a workable condition;
- Prevention of sudden failures;-
- efficient organization of maintenance and repair;
- increasing the technical utilization rate of the machines by improving the quality of the maintenance and repairs and reducing the repairs;
- Providing opportunities for the execution of the repair works on a schedule, consistent with the production processes;
- timely delivery of the necessary spare parts, materials and consumables.

Regulating the periodicity of repairs over time does not reflect the probable process of wear (aging) of machine parts and hence the need to restore their suitability. Therefore, repairs occur in most cases prematurely or with delay.In the practice of repairing the machines in agriculture, the following strategies are mainly applied: forced repairs; conducting repairs in plan order and a combined strategy with elements of both strategies.

The required pool of spare parts to maintain the robotability of the machines is determined by the formula:

$N = H(t_o).N.m,$

Where $H(t_0)$ is the recovery function (failover flow characteristic);

N_0 - number of machines from the reviewed group/aggregate;

m - number of same elements in a particular machine.

The Standardized forecasting period t_0 is determined by the formula:

$t_0 = t / q\,\bar{t}$,

where t is the forecasting period of the number of failures (spare items);

$\bar{t}$ - the average resource value of a new item;

q - the factor that takes into account the change in the spare elements resource as compared to the resource of the new elements (0,8≤q≥1,0).

The average number of failures or the expected need for spare parts to maintain the machine's working ability in the range [0, t], which represents the function H (t), should be determined for each of the main strategies.

The aim of the research is to determine the function of recovery (flow characteristics of refusals) during scheduled maintenance impacts, forced / unplanned / repair effects and combined / planned and unplanned / repair impacts.

Planned repairs.

In this case, the machine components are repaired after a set application time has elapsed, which is a random value set with a mathematical expectation distribution function T_n. The repairs have a plan-warning character that guarantees a certain level of reliability of the machine components.

Assuming that the prophylactic recovery is realized at a strictly fixed moment of time T_n, the probability of non-planned repairs for the 0-T_n period will be $P_a = \int_o^{T_n} fs(t)dt,$ probability of the planar effects up to the moment T_n equal to $P_n = 1 - P_a$.

The mathematical model of this strategy is derived under the following conditions:

$$F_1(t) = \begin{cases} 0 & t < 0, \\ 1-\exp[-\lambda_1 t] & 0 \le t \le T_1 \\ 1 & t \ge T_1, \end{cases}$$

$$F(t) = \begin{cases} 0 & t < 0 \\ 1-\exp[-\lambda t] & 0 \le t \le T \\ 1 & t \ge T\ . \end{cases}$$

The distribution functions can be recorded in the form of :

$$F_1(t) = \rho(t) - \rho(t).\exp[-\lambda_1 t] + \rho(t - T_1)\exp[-\lambda_1 t],$$

$$F(t) = \rho(t) - \rho(t).\exp[-\lambda t] + \rho(t - T)\exp[-\lambda t],$$

where $\rho(t)$ is the Heaviside step function.

$\rho(t) = [\ \frac{0 nput < 0}{1 nput \ge 0},$ which has a cut at t=0 from first period and borders on the left:

λ_i is the intensity of the i-stream of recovery;

T- is the moment of cut.

The Laplace transform can be written in the following way:

$$F_1(s) = \{\lambda_1 + s.\exp[-(s+\lambda_1)T_1]\} / s(s+\lambda_1);$$

$$F(s) = \{\lambda + s\exp[-(s+\lambda)T]\}. / s(s+\lambda)$$

We also replace the recovery function:

$$H(s) = \{(s+\lambda)(\lambda_1. + s\exp[-(s+\lambda)T]\} / s^2(s+\lambda_1)(1-\exp[-(s+\lambda_1)T_1.$$

When a sufficient length of the course of use, ie $t \to \infty (s \to 0)$,, by applying Wiener's tauberian theorems the statement is simplified and takes the form

$$H(s) = \lambda / s^2(1-\exp[-\lambda T]).$$

Using the Inverse Laplace transform we get:

$$H(t) = \lambda t / (1-\exp[-\lambda T]),$$

Which is expected since with $t \to \infty$ the impact of $F_1(t)$ stops working.

Forced (non-plan) repair.

In accordance with this strategy, resource failures occur at random times and are eliminated through repair actions to help the machine get into a different state from the original (new) machine. Planned preventive repairs are not carried out.

Let $t_1,t_2,..,t_n$ are the successive moments of occurrence of resource failures. The probability nature of such a stream of events can most simply be described by setting the time interval between the moments of events (t_{i-1},t_i), where $i=1,2,\dots,n$; $t_o=0$ и $t_i>t_{i-1}$. We set $T_i=t_i-t_{i-1}, i\geq 1$, $t_o=0$.

It is known that the flow of homogeneous events is determined if each $n \geq 1$ is assigned a random vector distribution [T1, T2, ..., Tn], where n is the number of intervals between failures.

If the flow has limited consequences, i.e. the random variables $[T_1,T_2,\dots,T_n]$ are independent of the set and its set of functions $F_i(t)=P\{T_i<t\}$, i.

After the first resource failure, the independent times of $T_i=t_i-t_{i-1}$ between two consecutive rejections are represented by the same distribution functions F(t),i.e. $F_2(t)=F_3(t)=\dots=F_n(t)$, and time T_1 until the first failure is allocated to the probability law F1 (t), so called recurrent flow with delay,which is defined woth the probability:

$$P\{T_i<t\}=F(t); \quad P\{T_1<t\} =F_1(t).$$

Therefore, this strategy is fully adequate with the models considered in the theory of recovery.

For practical application, the recovery function is of interest, which, as is known, represents the mathematical expectation of the number of recoveries up to the moment t, i.e. H(t)=M{N(t)}.

When using the Laplace transform, the equation of the restore function is as follows:

$$H(s)=f_1(t) /[s(1-f(s))]=F_1(s) / [1-sF(s)],$$

where $F(s)=\lambda /s(s+\lambda)$, because

$$F(t)=1-\exp[-\lambda tt], aF_1(s)=\lambda_{11}/s(s+\lambda_1),$$
$$F_1(t)=1-\exp[-\lambda_1 t].$$

Then $H_s=\lambda_1(s+\lambda)/s^2(s+\lambda_1)$ and if we use the inverse Laplace transform we get

$$H(t)=\lambda t+(\lambda_1-\lambda)(1-\exp[-\lambda_1 t])/\lambda_1,$$ and

with $t\to\infty (s\to 0) H(t)=\lambda t,$ which is expected because when $t\to\infty$ the distribution of the pre-repair period of the machine ceases to affect.

Combined strategy.

The repair impacts of this strategy are performed at the time of failure or at a predetermined planning moment, but the planning and failure moments alternate. It has been shown that the optimal option for planned repairs is to carry them out at strictly defined moments of operation of the machine. In real conditions, due to refractory repair impacts, these impacts do not occur at the set points. In this case, the restoration is carried out at random moment ξ with a distribution function $F_n(t)=P\{\xi<t\}$ and a distribution density $f_n(t)$. Typically, the distribution Fn (t) has the character of a normal distribution law with a mathematical expectation equal to $T_п$.

The distribution of the duration of fault-free operation is justified by the internal properties of the machine, and the distribution $F_n(t)$ characterizes the external to the machine organizational causes arising in the process of considering it as an element of some "larger" system.

Under the terms of this strategy, two states E_1 and E_2 are possible. Initially, the system is in the E_1 state. Time span intervals in E_1 are random variables t_i with the same distribution function $F_1(t)$, and time intervals $t_1^{/}$ added in E_2 times have the same distribution function $F_2(t)$.

We assume that all included random values are independent. In other words we have two types of elements with continuity of nonstop work $\{t_1,t_2,\dots,t_n\}$ и $\{t'_1,t'_2,t_3^{/},\dots,t_m^{/}\}$ and the respective density of distribution $f_1(t)$ and $f_2(t)$.

The main feature of this recovery process is the restore function for two types of elements and is given in the following form with the transformation of Laplace:

$$H_1(s)=f_1(s) /s\{1-f_1(s)f_2(s)\};$$
$$H_2(s)=f_1(s)f_2(s) / s\{1-f_1(s)f_2(s)\}.$$

When animalizing the process, it is more convenient $H_1(s)$ and $H_2(s)$ to depend on the distribution functions $F_1(t)$ и $F_2(t)$. for that purpose, when using the connection f(s)=sf(s), we can write:

$$H_1(s)=F_1(s)/ 1-s^2F_1(s)F_2(s)\},$$
$$H_2(s)=sF_1(s).\ F_2(s) / \{1-s^2F_1(s).\ F_2(s)\}.$$

We review the recovery process with exponential functions of allocating intervals between recoveries.

The two distributions are cut and have the following types:

$$F_1(t) = \begin{cases} 0 & t<0 \\ 1-\exp[-\lambda_1 t] & t\leq T_1 \\ 1 & t>T_1 \end{cases}$$

$$F_2(t) = \begin{cases} 0 & t<0 \\ 1-\exp[-\lambda_2 t] & t\leq T_2 \\ 1 & t>T_2. \end{cases}$$

The Laplace transform are written as follows:

$$F_1(s)=(\lambda_1+s.\exp[-(s+\lambda_1)T_1])/s(s+\lambda_1)$$

$$F_2(s)=(\lambda_2+s.\exp[-(s+\lambda_2)T_2])/s(S+\lambda_2).$$

And we get for $H_1(s)$ and $H_2(s)$ respective:

$$H_1(s)=\frac{[\lambda_1+s\exp[-(s+\lambda_1)T_1]](s+\lambda_2)}{s^2\{s+\lambda_1+\lambda_2-\lambda_1\exp[-(s+\lambda_2)T_2-\lambda_2\exp[-(s+\lambda_1)T_1]-} \to$$
$$\to \frac{}{-s\exp[-(sT_1+sT_2+\lambda_1T_1+\lambda_2T_2)]\}};$$

$$H_1(s)=\frac{[\lambda_1+s\exp[-(s+\lambda_1)T_1]](s+\lambda_2)}{s^2\{s+\lambda_1+\lambda_2-\lambda_1\exp[-(s+\lambda_2)T_2-\lambda_2\exp[-(s+\lambda_1)T_1]-} \to$$
$$\to \frac{}{-s\exp[-(sT_1+sT_2+\lambda_1T_1+\lambda_2T_2)]\}};$$

$$H_2(s)=\frac{[\lambda_1+sesp[-(s+\lambda_1)T_1][\lambda_2+s\exp[-(s+\lambda_2)T_2]}{s^2\{s+\lambda_1+\lambda_2-\lambda_1\exp[-(s+\lambda_2)T_2]-} \to$$

$$\rightarrow \overline{-\lambda_2 \exp[-(s+\lambda_1)T_1 - sesp[-(sT_1 + sT_2 + \lambda_1 T_1 + \lambda_2 T_2]\}}.$$

For large values of t ($s \rightarrow \infty$) the elements functions of restoring from the first and second types are:

$H_1(t)=H_2(t)=$

$$\lambda_1\lambda_2 t\{\lambda_1 + \lambda_2 - \lambda_1 \exp[-\lambda_2 T_2] - \lambda_2 \exp[-\lambda_1 T_2]\}^{-1}.$$

The recovery process at a large enough value of t becomes stationary and the recovery functions for both types of elements are equal. If $T \rightarrow \infty$, the expression will look like this: $P\{T_i<t\}=F(t)$; $P\{T_1<t\}=F_1(t)$, in the case of continuous functions of distribution of the interval between recoveries.

Conclusions:

1. The main strategies for management of the reliability of the agricultural machinery- forced execution of the repairing impacts (after failure), implementation of repair impacts in a planned order and a combined strategy with elements of the first two strategies have been analyzed.
2. A study was performed and analytical dependencies were obtained to determine the function of recovery (failure characteristic of the failures) of the machinery components in case of forced repairs (after failure), conducting repairs on a planned order and a combined strategy.

References :

1. Cox D., V. Smith Theory of Recovery. M., 1967.
2. Klimov G. Stochastic service systems. -M., 1966.
Barlow R., F.Proshan Mathematical Theory of Reliability. M., 1984.
3.Tasev G. Investigation of the flow of failures taking into account the repair effects - NMK, Kharkov, 1990, p. 51-58 ..
4.Spiridonov G., G.Tasev Some theoretical and applied aspects of the repair and maintenance of agricultural machinery.-Ruse, 1981, 336 pp.
5.Ivanova N., K. Georgieva. Development and research of a mathematical model for determining the flow characteristics of machine failures. Yambol 30-31, 2014, International Scientific Conference "Technology, Technology Education". ICTTE 2014, with 110-116.