

# DETERMINING THE LEVEL OF RELIABILITY OF SELF-PROPELLED AGRICULTURAL MACHINERY USING THE METHOD OF INSTANTANEOUS OBSERVATIONS

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**Summary:** To solve the tasks related to the operational management of the technical condition of self-propelled agricultural equipment the method of momentary observations to quickly assess the level of reliability of self-propelled agricultural equipment was improved.

A comparative study of the reliability of the self-propelled agricultural machinery / harvesters / classic method and the method of current observation, and it has been found that the accuracy of the results obtained by the method of current observation satisfy the requirements for practical usage.

**KEYWORDS:** REFUSAL, WORK TILL REFUSAL, THE FLOW RATE OF REFUSALS, SCHEDULED MAINTENANCE, PLANNED REPAIRS, MATHEMATICAL MODEL, RELIABILITY, COEFFICIENT OF READINESS.

Used test methods in the theory and practice of reliability are of long duration and to conduct accelerated testing usually require special stands and expensive measurement equipment. Meanwhile tasks regarding the operational management of the technical condition of the machines, require the development of express methods for assessing the level of reliability.

When the machines are working it is possible in operating order to organize observation at certain times and to establish what their condition is. We accept that we have N machines that will be used till manufacture of  $t_n$  (Fig. 1). During the operation they refuse at time moments  $t_i^j$  ( $\forall i = \overline{1, N}$  and  $j = \overline{1, m}$ ), and their performance was recovered in the moments  $t_{b_i}^j$  where j is the

number of refused and i - the number of machine. At certain times  $t_{M_k}$  the technical condition of the machine is determined – we establish in what condition it is, capable or incapable of working (in a state of refusal) [3].

When there is a sufficient number of objects N, from Figure 1, the likelihood to establish that the first machine is in working condition is proportional to the time being in this state:

$$(1) \quad P = \frac{n_1}{N} = \frac{\sum_{i=1}^N \sum_{j=1}^m t_i^j}{Nt}$$

Where  $n_1$  is the number of machines found in working condition;

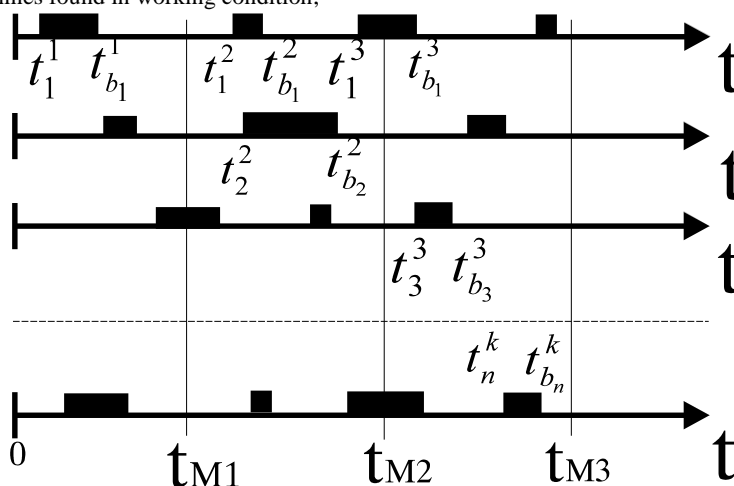


Fig. 1. Scheme of using the current live observations

From this ratio will readily determine by the famous

formula  $Kr = \frac{t_{cp}}{t_{cp} + t_b}$ , then substitution of (4) we get

N - total number of machines which are monitored;  
m - the number of refusals in the i-th machine.

Similarly, the probability of failure is determined by the following relationship:

$$(2) \quad F(t) = 1 - P(t) = \frac{n_2}{N} = \frac{\sum_{i=1}^N \sum_{j=1}^m t_{b_i}^j}{Nt}$$

Where  $n_2$  is the number of machines present in the non-operational. From the ratio

$$(3) \quad \frac{n_1}{n_2} = \frac{\sum_{i=1}^N \sum_{j=1}^m t_i^j}{\sum_{i=1}^N \sum_{j=1}^m t_{b_i}^j}$$

After conversion we get that

$$(4) \quad t_{cp} = \frac{n_1}{n_2} t_b ; n_2 \neq 0,$$

Where  $t_{cp}$  is average work out till failure;  
 $t_b$  - average time to restore the performance of the objects.

$$(5) \quad Kr = \frac{\frac{n_1}{n_2} t_b}{\frac{n_1}{n_2} t_b + t_b} = \frac{n_1}{(n_1 + n_2)}$$

Similarly, the coefficient of technical use will be

$$(6) K_{TK} = \frac{n_1}{n_1 + n_2 + n_3 + n_4}$$

Where  $n_3$  is the number of machines that are in scheduled maintenance;

$n_4$ - the number of machines located in planned repair.

The parameter of refusals flow  $\omega(t)$  in stationary proses ( $t \rightarrow \infty$ ) was

determined by the dependency  $\omega(t) = \frac{1}{t_{cp}}$ , then:

$$(7) \omega(t) = \frac{n_2}{n_1 t_b}$$

And the average number of failures at time  $t$  is

$$(8) m_{cp}(t) = \omega(t) \cdot t = \frac{n_2}{n_1 t_b} \cdot t$$

Similarly, the expression (4) can determine the average resource of the machine:

$$(9) T_{cp} = \frac{n_1}{n_5} t_p$$

Where  $t_p$  is the average time in which the machine spends in major renovation;

$n_5$ - number of machines in overhaul.

It is known that the moments of occurrence of refusals and time to remove them are random magnitude and momentary observations are conducted per plan, at set intervals. Then the probability that the observer will begin monitoring during the recovering if the object's performance is allocated under the law of uniform distribution. Here mathematical expectation of time from the beginning of occurrence of refusal till observer's fixing it is:

$$(10) t_b^H = \frac{1}{2} \sum_{i=1}^{n_2} t_{bi}$$

Thus, the average observation time of the machine in a state of refusal is equal to half of the average time of recovery of its working capacity. Then

$$t_b = 2 \cdot t_b^H$$

i. e., the average recovery time of the object is equal to double the time from the beginning of the failure of products until its fixing in a state of refusal. For practical calculations it is appropriate to use the following formula

$$(11) t_b = \frac{2 \sum_{i=1}^{n_2} t_{bi}^H}{n_2}$$

Where  $t_b^H$  is the time from the beginning of occurrence of the  $i$ -th refusal until its fixing at the time of monitoring.

The required number of momentary observation, i. E. Fixed the machine operable or non-operational, is based on the formula for the accuracy of an assessment [1,2]

$$(12) \varepsilon = t_\beta \sqrt{\frac{P(1-P)}{n}}$$

where  $P$  is the probability of occurrence of a random event  $A$ , determining the state of the research object;

$t_\beta$  - the argument of the differential distribution function of Student;

$n$  - number of current observations.

$$\text{From here } n = t_\beta^2 P(1-P) / \varepsilon^2$$

The expression (12) is correct in a single instantaneous monitoring of machines. Therefore, when the number of momentary observations has to be greater than the number of machines ( $n > N$ ), then (12) takes the following form:

$$(13) \varepsilon = t_\beta \sqrt{\frac{P(1-P)}{\ell N}}$$

where  $\ell$  is the number of re-monitored machinery.

The formula (13) is true when the frequency of conduction of current observations ( $\tau$ ) greater than the maximum time for removal of failures  $t_{bmax}$ . ( $\tau > t_{bmax}$ ). Otherwise for repeated monitoring of denials whose time for removal of failures is greater than the frequency of current observations ( $t_b > \tau$ ) will again be included in the number of refusals. The probability of such failures is defined

by  $F(\tau) = \int_\tau^\infty \psi(t) dt$  where  $\psi(t)$  is the density of distribution of

recovery time.

Then the number of failures is re-registered

$$m_n = N \int_\tau^\infty \psi(t) dt$$

From here

$$(14) \varepsilon = t_\beta \sqrt{\frac{P(1-P)}{\ell N(1-F(\tau))}}$$

The expression (14) allows to find the necessary frequency for conducting the instantaneous observations. If the time allotted for assessing the reliability  $t_0 > t_{bmax}$ , the frequency is selected equal to  $t_{bmax}$  and the number of current observations are determined by formula (13), meaning:

$$N = \frac{t_\beta^2 P(1-P)}{\ell \varepsilon^2}$$

Otherwise, the frequency of momentary observations is found by converting the formula (14) taking into account that the recovery time is distributed by the exponential law, and  $\tau = t_0 / \ell$ . Then

$$\tau = \frac{t_0 N \varepsilon^2 (1 - e^{-\lambda \tau})}{t_\beta^2 P(1-P)} \quad \text{but} \quad \text{since}$$

$$e^{-\lambda \tau} = 1 - \frac{\lambda \tau}{1!} + \frac{(\lambda \tau)^2}{2!} - \rightarrow \infty \quad \text{and we take the first two}$$

terms,

$$(15) \tau = \frac{t_0 N \varepsilon^2}{(1-\lambda)t_\beta^2 P(1-P)}$$

In the period from 2005-2006, a study was conducted over the reliability of 10 combine harvesters, in the conventional way and by momentary observations. There were conducted 450 momentary observations and registered 403 cases of operational and 59 - non-operational. The aggregated data are given in Table 1.

To calculate the difference between the estimates as a benchmark, other results were used from prolonged observation. From the analysis of the accuracy of the result we come to the conclusion that the accuracy of the test method of momentary observations is sufficient for practical use.

**Table 1:** Characteristics of indicators of reliability of combine harvesters

Characteristics	Methods of evaluation		Difference %
	continuous observation	momentary observation	
Work out –till-refusal	8.97	9.47	5.5
Ratio of readiness	0.866	0.872	0.69
Parameter of refusal flow, 10 <sup>-3</sup>	111	106	5.6
Work out till refusal in groups of complexity:			
I	20.71	18.54	10.5
II	17.20	16.90	1.7
III	196.75	190.08	3.4

### Conclusions:

1. The method of instantaneous observations used to quickly assess the level of reliability of self-propelled agricultural equipment is improved.
2. A comparative study was conducted of the reliability of self-propelled agricultural machinery / harvesters / in a classic method and the method of instantaneous observations.
3. It has been found that the accuracy of the results obtained by the method of momentary observation satisfy the requirements for practical usage.

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