Evaluation of economic efficiency for metrological maintenance system of measuring instruments for the weapons and military equipment parameters control

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Abstract

Metrological maintenance of measuring instruments for weapons and military equipment parameters control is carried out in order to provide reasonable conclusions about the serviceability, and, as a consequence, the suitability of measuring instruments for use as intended. However, today the metrological maintenance system of measuring instruments for weapons and military equipment parameters control requires improvement, taking into account modern requirements for weapons and military equipment, as well as development trends of the Ukraine Armed Forces. In order to prevent excessive expenditure of resources when carrying out metrological maintenance of measuring instruments for weapons and military equipment parameters control to ensure the correct decision-making regarding the technical condition of measuring instruments and a sample of weapons and military equipment in general, it is necessary to obtain estimates that will allow analyzing the measuring instruments for weapons and military equipment parameters control and to synthesize an optimal metrological maintenance system of measuring instruments for weapons and military equipment parameters control according to certain efficiency indicators, in particular, in terms of economic indicators. To determine the economic efficiency for metrological maintenance system of measuring instruments for weapons and military equipment parameters control, the article proposes to use a complex economic indicator, which takes into account the coefficient of performance by a sample of weapons and military equipment of the assigned task, the economic effect (that is, benefit), as a result of a sample of weapons and military equipment using for its intended purpose and losses associated with the failure to fulfill its tasks, respectively.

Key words: economic efficiency, metrological maintenance, weapons and military equipment, measuring instruments, parameters control.

Introduction

When solving the problems of optimizing the metrological maintenance system (MMS) of measuring instruments for weapons and military equipment (WME) parameters control, it is first of all necessary to substantiate the indicators of its effectiveness.

The efficiency of the MMS of measuring instruments is characterized not only by the achievement of high results of its work, but also by a small expenditure of monetary and other resources. Therefore, there is a need to calculate the economic efficiency of MMS of measuring instruments for WME parameters control to assess the optimality of its construction.

In our opinion, any material costs for the operation of measuring instruments, even significant ones, should be compensated for by the material effect from the use of a WME sample for the intended purpose, the parameters of which are controlled by these measuring

instruments (Ignatkin V. U., Lytvynenko V. A., 2019).

Material and methods

To date, when solving the problems of assessing the economic efficiency in the field of metrological maintenance, various approaches are used (Hyzhniak V. V., 2014; Kononov V. B., Sheviakov Yu. I., Kushneruk Yu. I., 2016; Chekryzhev N.V., Koptev A.N., 2015). However, they do not take into account the material effect of carrying out metrological maintenance, but only take into account the costs of operating the measuring instruments

Thus, the purpose of the article is to substantiate a complex indicator of economic efficiency, which takes into account the material effect of using a WME sample for their intended purpose and obtaining conditions for the synthesis of an optimal MMS of measuring instruments for WME parameters control.

Results and discussion

Refusal to carry out metrological maintenance of measuring instruments for WME parameters control may lead to their failure, which in turn will lead to the fact that a faulty sample of WME will be allowed to perform important tasks and, as a result, will be applied corresponding material losses C^-.

On the other hand, the refusal to carry out metrological maintenance will reduce the cost of operating WME samples by an amount determined by the cost C_{MM} of carrying out metrological maintenance of measuring instruments for monitoring their parameters. Let us introduce the coefficient of economic efficiency of carrying out metrological maintenance of measuring instruments for WME parameters control $K_E = C_E^{\text{MM}}/\text{C}_\text{E}$, where $\text{C}_\text{E}^{\text{MM}}$, C_E – the economic effect of the use of a sample WME for the intended purpose during the metrological maintenance of the its parameters measuring instruments and without it in accordance (Chinkov V.N., Herasimov S.V., Yakovlev M.Yu., 2001).

Then the indicator of the economic efficiency of carrying out metrological maintenance of measuring instruments for WME samples is written as $\text{K}_\text{E} = \text{C}_\text{E}^{\text{MM}}/\text{C}_\text{E} > 1$, where at $K_E>1$ the economic effect from the use of a WME sample for its intended purpose is greater than the cost of carrying out metrological maintenance of the measuring instruments of its parameters and it is economically feasible. If $K_E <1$, then it is necessary to revise the economic requirements for the MMS, that is, to reduce the cost of metrological maintenance operations.

Let's calculate the values of the economic effect functions $\text{C}_\text{E}^{\text{MM}}$, C_E.

The function of the economic effect from the use of a WME sample for the intended purpose C_{ef} is presented in the form (Chinkov V.N., Herasimov S.V., Yakovlev M.Yu., 2001):

$$C_{ef} = K_{WME}C^+ - (1 - K_{WME})C^- - C_{WME} \qquad (1)$$

where, C^+ – a value that determines the economic effect (benefit) as a result of the use of a WME sample for its intended purpose;

C_{WME} – a value that determines the cost of operating a WME sample;

K_{WME} – a numerical coefficient that takes into account the fact that the WME sample fulfills the assigned task and depends on the operating parameters of the WME sample.

Consider the boundary conditions for expression (1). When K_{WME} = 1 he takes species $\text{C}_{ef} = -\text{C}^- - \text{C}_{WME}$, where the sign "–" means that when the sample of WME is not fulfilled the tasks, the losses will amount to the magnitude of the material losses associated with the failure the task of the WME sample and the operation cost.

We define the value of the coefficient K_{WME} when conducting the metrological maintenance of measuring instruments for WME parameters control – K_{WME}^{MM} and without it – K_{WME} by the following expressions (Chinkov V.N., Herasimov

S.V., Yakovlev M.Yu., 2001):

$$K_{WME}^{MM} = P_R^{MM} K_P K_F \quad (2)$$

$$K_{WME} = P_R K_P K_F \quad (3)$$

where K_P, K_F – numerical coefficients that determine the level of qualification of staff serving the weapon sample and the level of external factors influence for the use of a WME sample by appointment (varies in the range from 0 to 1 and are determined on the basis of experimental data or expert assessments);

P_R^{MM} – the probability of a WME sample good condition after the metrological maintenance of measuring instruments for its parameters control;

P_R – the probability of a weapons sample good condition without conducting the metrological maintenance of measuring instruments for its parameters control.

The cost of WME sample exploitation is defined as the total costs of its stay in various states of operation (for example, the state of applying a sample of weapons for the purpose, repair of the weapons sample, checking the functioning, diagnosis, etc.) and the transitions between them and are calculated using the expression:

$$C_{WME} = \sum_{i=1}^{N} C_i P_i(\chi) + \sum_{i=1}^{N} \sum_{j=1}^{N} C_{ij} P_i P_{ij}(\chi), \quad (4)$$

where Ci, Cij – is the cash costs for the operation of the WME sample, respectively, when it is located in the i-th state, $i = 1, N$, and when switching from the i-th state in the j-th state, $j = 1, N$;

N – number of operating conditions of the WME sample considered;

χ – vector of the parameters of the WME sample operation (for example, the frequency of the metrological maintenance of measuring instruments for its parameters control, the mean operating time to failure, etc.);

$P_i(\chi)$ – the probability of finding the weapons sample in i-th condition;

$P_{ij}(\chi)$ – is the probability of weapon sample transitions from the i-th to the j-th state.

The probabilities $P_i(\chi)$, $P_{ij}(\chi)$ are rigidly related to the vector of parameters χ, so the obtained function (4) depends on the parameters of the operation of the weapon sample, including the parameters of metrological maintenance of measuring instruments (for example, the lower the frequency, the greater the cost of metrological services, etc.).

Taking into account expressions (1-3), the functions of the economic effect $\mathrm{C_E^{MM}}$, C_E when carrying out metrological maintenance of measuring instruments for WME sample parameters control and without it, will take the following form:

$$C_E^{MM} = P_R^{MM} K_P K_F C^+ - (1 - P_R^{MM} K_P K_F) C^- - (C_{WME} + C_{MM}),$$

$$C_E = K_{WME} C^+ - (1 - K_{WME}) C^- - C_{WME} = P_R K_P K_F C^+ - (1 - P_R K_P K_F) C^- - C_{WME}$$

Substituting these relations into equation (1), we obtain:

$$\mathrm{K_E} = \frac{\mathrm{P_R^{MM} K_P K_F C^+ - (1 - P_R^{MM} K_P K_F) C^- - (C_{WME} + C_{MM})}}{\mathrm{P_R K_P K_F C^+ - (1 - P_R K_P K_F) C^- - C_{WME}}} \quad (5)$$

Simplifying the equation (5), and since the values of the probabilities $\mathrm{P_R^{MM}}$, P_R and the values of the K_P, K_F coefficients can take values in the range [0, 1], then we obtain the condition for the synthesis of an optimal MMS of measuring instruments for WME parameters control during its operation:

$$\frac{\mathrm{C^+ + C^-}}{\mathrm{C_{MM}}} > 1 \quad (6)$$

It can be seen from inequality (6) that the MMS of measuring instruments for WME parameters control is built correctly only when the economic effect from the use of a sample of weapons for their intended purpose is greater than the cost of carrying out metrological maintenance of measuring instruments of its parameters control. In this case, it is economically feasible to carry out metrological

maintenance of measuring instruments for WME parameters control, otherwise the MMS of measuring instruments for WME parameters control is not built optimally.

Conclusions

Thus, as an indicator of the economic efficiency of the MMS, it is recommended to use a complex economic indicator, the peculiarity of which is that it takes into account not only the costs of the development and operation of measuring instruments for WME parameters control, but also the economic effect of using a sample of weapons, the parameters of which are measured by appropriate measuring instruments, as intended.

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