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Computer database containing the results of the control of the technical condition of the armament equipment

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The paper presents issues related to the performance and parameter monitoring of armament equipment, in particular anti-aircraft missiles. A mathematical model of parameter observation matrix from periodic inspections of technical condition of armament equipment is described. Particular attention was paid to the presentation of the assumed software solutions of the developed database.

KEYWORDS: *condition based maintenance, anti-aircraft missiles, database*

Introduction

Armament equipment (AE) used in modern battlefields should be characterized by high operational readiness and efficiency. The effective operation of AE depends primarily on its properties and determines its quality.

One of the main factors determining the quality of AE is its reliability, which is shaped during design and manufacture. During the AE operation phase, previously acquired reliability properties are applied. As a result of using the AE, reliability properties deteriorate and thus the readiness and quality of AE performance decreases.

Therefore, there is a need for periodic control of technical condition of AE, because the diagnostic information obtained in this way is provided, among others, by knowledge about reliability changes during the operation phase.

A particular example of AE is the n -element population of anti-aircraft missiles, for which storage is the dominant operating condition, with periodic inspection of technical condition. The average time the missiles are in storage is much longer than the sum of their average times in other operating states:

$$T_p \gg \sum_{i=1}^n T_i \quad \text{dla } i = \overline{1, n}$$

where: T_p – average storage time of missiles, T_i – average duration of the i -th operational state, n – number of operational states occurring in the missile operation process (excluding the storage state).

The purpose of the paper is to present the concept of a computer database developed for the purpose of collecting, storing and processing the results of periodic inspection of anti-aircraft missiles technical condition.

Presented concept meets the challenges posed by modern database applications, which should be characterized by security of data collection and storage, reliability in operation, intuitiveness of use, etc. Dynamically developing current information technologies offer many possibilities and solutions for creating and using specialized and efficient databases.

Mathematical model of technical condition control

To describe the AE technical control process, it is convenient to adopt methods of statistical analysis in matrix form. During each technical inspection of AE, operational data is obtained in the form of:

- number of m measured AE operating parameters;
- set of values of measured AE work parameters $\Phi = \{X_1, \dots, X_m\}$, where X_m – value of the m -th AE work parameter;
- set of time units $T = \{1, \dots, t\}$, in which the parameter value was measured.

Due to simplicity of the record, the results of measurements from the AE technical condition control are well presented in the form of an observation matrix [1]:

$$X = [x_{ij}] = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1p} \\ x_{21} & x_{22} & \dots & x_{2p} \\ \dots & \dots & \dots & \dots \\ x_{n1} & x_{n2} & \dots & x_{np} \end{bmatrix} \quad i = \overline{1, n}; \quad j = \overline{1, p}$$

where: x_{ij} – value of the feature X_j ($j = \overline{1, p}$) noted for the i -th ($i = \overline{1, n}$) examined object (i -th element of the sample).

If observations are made at specific times, the observation matrix X takes the form $X = [x_{ijl}]$, in which: $i = \overline{1, n}; j = \overline{1, p}; l = \overline{1, t}$.

The use of spatial representation means that the set $\{X_1, \dots, X_p\}$ stands out in p -dimensional space. In this way, each P_i object is numerically described using the $\mathbf{x}_i[1 \times p]$ vector of the form $\mathbf{x}_i = [x_{i1}, \dots, x_{ip}]$.

The proposed method of describing the AE technical inspection process facilitates inference about the quality of inspection results due to the numerical form of the observation matrix.

Description of adopted program solutions

During development of the database concept, the following functional requirements for the system were adopted [2]:

- automatically adding the check results records;
- using the CRUD function (create, read, update, delete) on database objects;
- the use of search, sorting and any data change function in the search results table;
- using the function of automatic completion of check results based on the probability of occurrence of individual parameters values;
- system for archiving changes in the database based on blockchain technology;
- password masking during login and multi-level login verification using SMS password;
- implementation of algorithms supporting operational decision making;
- automation of generating test reports and the ability to send them to authorized persons.

As a result of the implementation of these assumptions, the following system features of the database application were achieved:

- transparency and intuitiveness – the system interface is legible and easy to use. In the application, proper placement of objects was ensured, in accordance with the trends set by Robert J.K. Jacobs [3];
- functionality – the system provides useful tools that make it easier for the user to perform tasks and increase work efficiency;
- security – the system ensures security for the database user as well as information stored in it. User security was achieved by masking the password when logging in and verifying access by means of an SMS, while data security was ensured by encrypting stored access passwords and using blockchain technology mechanisms in the stored information archiving subsystem;
- minimizing the possibility of making mistakes or informing the user about these errors – messages informing about errors are displayed immediately after entering the wrong record and indicate how to solve the problem;
- clear communication in the program–user relationship. Messages informing about the state of execution of processes initiated by the user, are displayed;
- system integrity – all system components operate on the same resources. The option of making changes to data using unauthorized functions has been excluded;

- modularity – the system is divided into modules that can work independently of each other; they have a single liability rule.

System structure model

A detailed description of the process of obtaining, collecting and processing information is provided in [4, 5]. Fig. 1 presents the concept of the system for collecting and analyzing the results of periodic inspection of technical condition of anti-aircraft missiles.

Three main stages should be distinguished in the process of acquisition and processing of data from periodic control of missiles:

- first stage – data acquisition; important information about the technical condition of the examined objects is obtained by means of the Automatic Test Equipment Cabin (ATEC);
- second stage – data collection; technical staff initially processes the acquired information and can enter it through the Data Acquisition Stand (DAqS) into the Computer Database (CDB). Communication between DAqS and CDB is based on a data exchange protocol via the internet;
- third stage – data analysis, covering operations performed on data to generate information necessary to develop decisions in the process of controlling the anti-aircraft missile operation.

Fig. 1. Block diagram of the system for the acquisition and processing of periodic inspection results of anti-aircraft missiles technical condition [2]

Computer Database

The final result of the missile technical condition control is the measurement of missile parameters (deviations from the nominal value) in analog form. Data prepared in this way is entered into CDB in a coded digital form, enabling its storage and further processing (analysis). The information stored in the CDB is supplemented with additional data, such as: missile number and batch, date of the test or checking data.

Entity relationship diagrams

Barker notation [6, 7] without entity attributes was used in the developed database application. There are binary relationships and one ternary one (fig. 2). Association types used in relationships are one-to-many – their existence is mandatory.

Fig. 2. Diagram of the adopted entity relationships in the database application [2]

Relational model

Fig. 3 presents the adopted structure of a set of tables with columns and types of introduced variables.

Missiles Missile System Id_missile_system: int(11) System_name: text	Missile Missile Id_missile: int(11) Id_unit: int(11) Serial_number: varchar(10) Id_missile_system: int(11) If_efficiency: int(1)	Missile Unit Id_unit: int(11) Unit_name: text Place: text Missile Rank Id_rank: int(11) Rank_name: text	Missile Missile Check Id_missile_check: int(11) Id_evaluator: int(11) Id_missile: int(10) Date_of_check: date Date_of_service_life: date S1: int(11) (...) S45: int(11) SUM_TIME: int(11) S_O: int(11)
Missile Evaluator Id_evaluator: int(11) First_name: text Surname: text Id_rank: int(11)			

Fig. 3. Tables in the database application [2]

Data Analysis Stand

The main functional element of the developed application is the so-called Data Analysis Stand (DAS), which includes the following modules:

- Database Management Module (DMM), which is used to perform basic operations on records, i.e. to add, delete, edit, search or sort records by defined categories;
- Knowledge Discovery Module (KDM), which is used to obtain information using statistical analysis methods of data contained in CDB. Here are, among others:
 - quantitative methods – allow to infer trends in changes in controlled AE parameters;
 - correlation matrices – enable correlation of controlled AE parameters and their spread;
 - cluster analysis methods (including data agglomeration and grouping procedures) – allow detecting dependencies of AE component working parameters;
 - methods of grouping objects and their features – the result of grouping data is a performance map that illustrates the nature of changes in controlled parameters for missile lots;
 - time series methods – allow observation of changes in controlled AE parameters over time;
- Decision Support Module (DSM), which is equipped with a number of functionalities (using, among others, the results of KDM analyses), such as:
 - indicating the missiles to be used first;
 - mechanisms for automating the introduction of check results;
 - tools for identifying the relationships between damage to AE components and sets;
 - tools supporting the way of conducting analyses and reporting.

System users' behavior model

The application has four types of users with different levels of user–system interaction. Those are:

- administrator – a person responsible for supervising and maintaining the system's operation, who responds to problems and introduces program updates;
- user acquiring data – a person responsible for the correctness of the inspection of the technical condition of the AE and for entering data into the database system;
- analyst – a person responsible for generating reports, monitoring emerging trends and searching for dependencies between data that may be relevant in the process of developing decisions on missile operation (receives tasks from the decision maker and consults with him periodic reports);
- decision maker – a person who sets tasks for other system users (especially the analyst), e.g. tasks related to the preparation of the form or scope of the generated periodic report.

The adopted model of system users behavior is symbolically presented in the form of the use case diagram in fig. 4. The diagram contains only selected functions and relationships of potential system users. The administrator role has been intentionally omitted, as he has the authority to affect almost all system components.

Interpretation of the case diagram begins with the relationship between ATEC and CDB. This relation is mediated by the user who obtains data, who enters the DAqS results of the control of the technical state of the missiles and stores them in CDB. Using SQL queries, data saved in CDB can be processed by other users, who have access to individual application modules. Particularly noteworthy is the relationship between the KDM and DSM modules. It can be based on the results of analyses obtained using external computing applications "attached" by the analyst.

Fig. 4. The use case diagram for database application [2]

Summary

Undertaking the subject of developing a computer database of missile technical inspection results is related to the need to extend their service life. The works were carried out in two stages. First, works aimed at developing the method for assessing the quality of AE operation, allowing the indication of missiles for wear first, and then – at developing the IT system design, resulting in the solutions presented in the paper. Results of analyses applying the developed method allowed to determine the relationship between changes in the reliability properties of missiles and their design solution. The result of the work in the database system are identified requirements and functionality of the application.

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