Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 15th International Scientific and Practical Conference. Volume IV, 131-137

Development Of A Program For Conducting Tests With Physical Samples Of A Defence Industry Product

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***Abstract*. The developed Program for Conducting a Test with Physical Samples of a Defence Industry Product is a systematic approach to scientific research related to the study, research, and collection of various types of data (information) on the researched object. The constructed and subjected to testing physical samples (models) of the product are used to confirm the correctness of the initial assumptions made. They are related to the possibility of improving the final product without changing the basic requirements for it. The search for an appropriate solution to the research task is related to the construction and testing of a new type of details. They are related to the accumulation of reliable spatial-geometrical data about the product and its reliability characteristics. In addition, to improve the visual perception of the physical objects, a Visual 3D model of the tested physical samples of a chemical power source (batteries) was developed and presented in the report using the capabilities of modern digital programs.**

Keywords: 3D model, physical samples, testing.

I. INTRODUCTION

The *Plan for the design, manufacture and testing of physical samples of a defence industry product* fulfils its functions by tracking all the main stages related to the commissioning of a defence product. It gives consistency, analogy and systematicity to the stages of the research while providing an opportunity to collect, systematize and evaluate the information obtained.

The information is used to study the material objects and the physical processes taking place with them. The studied object (physical model) should not be perceived only as a specific physical object but as a system consisting of various interconnected objects and phenomena. Knowing their totality determines the reliability of the product and its components.

The plan was drawn up on the basis of an in-depth study on the possibility of determining the reliability characteristics and their influence on the working mode of the products. It aims to trace and justify the main stages of the scientific research related to the development and testing of physical samples (models) to prove their reliability, operability and safety.

II. MATERIALS AND METHODS

Scientific research and didactic methods were used in the development of the Program for testing physical samples of a defence industry product. The literature used is within the relevant volume, and literary sources and the requirements for the research object specified in them are used for summary and analysis. The Program aims to offer an option for a logical sequence of stages in conducting tests with physical samples and to justify key points in the scientific research (Fig. 1). When presenting the results, didactic methods, taxonomic categories, as well as methods of selection and comparative analysis were used.

A software method was used to visualize the developed physical samples (Fig. 2), and for additional visualization of the research object, visual models of the interior of the power source, indicated in Figures 3 to 5, were built using a computer visualization program. The above-mentioned Program is a theoretical development that guides the conduct of a practical examination of products from the defence industry and structures the main elements in the conduct of this examination, specified in section III.

III. RESULTS AND DISCUSSION

The main goals set by the Program are related to structuring the stages in current and future developments, starting from the conceptual design to the construction of the final product. The core structure of the content concerns the main categories in the taxonomy – *knowledge, understanding, application, analysis,*

Print ISSN 1691-5402
Online ISSN 2256-070X
https://doi.org/10.17770/etr2024vol4.8204

synthesis, *evaluation.* Evaluative content is given on the basis of predefined criteria, selection of own evaluation criteria and their argumentation through examples presented in the figures in the paper.

Using B. Bloom's taxonomy, the following contributions can be formulated, which correspond in essence to its different levels. In the initial stage, a conceptual project is formed, which unites a certain category of *knowledge* through the possibility of grouping and defining the main task. To *understand* the essence of the problem, we choose a sequence of actions related to getting to know the characteristics of the studied object. Through direct research actions, an *application of the studied object* is sought, it is illustrated, constructed, demonstrated, proved, or an experiment is conducted. In order to *carry out an analysis*, we group, separate, select, reveal, grade or predict the characteristics of the researched object. The proposed program implies the use of the taxonomic category for the *synthesis* of acquired knowledge through its documentation, systematization, combination, modification, planning, modelling, design and presentation. Giving an *assessment* and its reasoning are the basis for determining the application, ergonomics and operability of the final product [1].

Fig. 1 presents a generalized algorithm of the sequence of stages that make up the Plan for the design, manufacture and testing of physical samples of a non-contact radio proximity fuse (VN-RL-82). The main tests to which the physical models are subjected are also indicated.

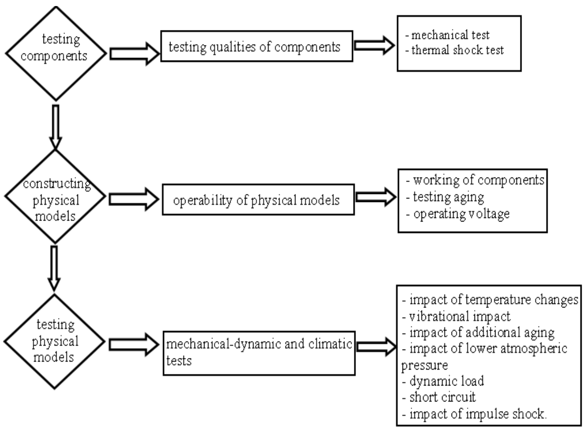

Fig. 1. Algorithm for conducting the testing of the constructed physical models

During the tests, in order to specify a certain characteristic of the final product, it is allowed to conduct additional tests to those indicated in Fig. 1.

A. Object and area of application of the plan

The presented plan determines the order of development, construction and testing of physical models (samples) of defence products (products and materials). It indicates the main requirements related to the implementation of verification and control and gives the value range of the conducted tests. It includes references and prescriptions from the standards listed below, their latest editions being valid.

− Bulgarian State Standard BDS 2.503 Unified system for construction documentation. Amendment Rules [2];

− Bulgarian State Standard BDS 2.601 Unified system for construction documentation. Operational documents [3];

− Military Standard VS 40069 Tactical-technical assignment [4].

B. Terminology and definitions used in the plan

Defence product **–** general name for a product or material whose purpose is to satisfy the needs of the ministry of Defence.

Products **–** products whose quantity is measured in pieces (specimens). The products are characterized by the fact that they have a resource that is used up during their operation.

Materials **–** products whose quantity is measured in units of length, area, volume, or mass (m, m^2, m^3, kg, etc.). They do not have a resource, but during their use, the materials themselves are used up.

Representatives of the contracting authority **–** a group of specialists for scientific and technical support tasked to check and agree the documentation, control the development and accept the defence products at the various stages of their development, implementation and production.

Contracting authority **–** the people under whose initiative the research is conducted.

The terminology dictionary has been created based on Military Standard VS 2.03:2007 – Development and implementation in the production of defence products – MoD № OH 736/16.11.2007 [5].

C. General conditions and main stages in the test program

The main concept project is related to the opportunity stated by the contracting authority for the accumulation of scientific research data for the construction, testing and improvement of a non-contact radio proximity fuse through the construction of physical samples for laboratory tests.

The plan divides the research process related to the collection and processing of information about the research object into standardized and unified stages. This is how purposeful management of the information processes related to the implementation of the task is carried out.

The main stages and activities in the construction, development and testing of the physical samples (models) and their components (mechanical part, power source and electronic part – considered as components of a defence product) are as follows:

First stage: Concept project (for the product) – it includes the development of the idea for an upgrade to a defence industry product, improvement of its mechanical part, and design of a modern electrochemical power source;

Second stage: Working project (for the product) and laboratory technology (for the materials) – this stage is related to constructing and conducting of the initial testing of the materials which the product is made of, as well as the creation of a visual 3D model;

Third stage: Testing sample (for the product) and testing batch (for the materials) – it is related to conducting the initial tests for the operability and capability of the product to perform the tactical-technical task or the production of an experimental batch of materials to be subjected to testing.

Forth stage: Testing batch (for products) and testing batch (for materials) – the purpose is to construct an experimental batch of fully constructed physical samples (models) of the product and an experimental batch of materials to be tested in a certified laboratory for reliability, operability and safety. The compatibility of the product with the requirements of the tactical-technical task is examined, taking all precautionary measures for the safe conduct of the tests (the product subjected to testing does not contain explosive substances) [6, 7].

a) *Concept project for the product*

The purpose of the concept project is to clarify the basic principles of operation and the possible options for technical design of the product and its constituent parts. An assessment is made which of the developed options will most fully satisfy the tactical-technical task. During the implementation of the concept project, research and development activities are carried out. They are carried out through research and experiments in a volume necessary to confirm the possibility of improving a non-contact radio proximity fuse and developing a modern power source based on selected conceptual solutions.

The tasks set for implementation of the concept project have been started through the development and construction of three variants of a chemical power source for a non-contact radio proximity fuse. A representation model and physical models of a power source and its components have been developed, researched and tested in order to justify the possibility of realizing the concept project. A technological and technical-economic analysis of the proposed options is carried out. An assumption is made about the possibility of improving a defence product.

Point *E* of this paper presents the developed 3D models of the chemical power sources, which are part of the concept project and are yet to be tested.

b) *Working project for the product*

The purpose of the working project is to determine the main technical characteristics of the product and its components, based on an approved conceptual design, through the production and testing of models (samples). An opportunity is being sought to confirm the technical characteristics and to meet the requirements of the tactical-technical task in the experimental production [8].

During the development of the working project, activities necessary to obtain a complete understanding of the design of the product being developed are carried out, an assessment is made of its compliance with the tactical-technical task, and its technology and complexity are taken into account. The indicators of ergonomics (method of packaging and transportation) and operation are defined and discussed to meet the technical requirements of safety and occupational hygiene. This is achieved by building and researching physical models that fully and accurately repeat the real characteristics of the final product.

In general, during the development of the working project, the researcher performs the following main activities:

- Develops and substantiates the technical characteristics and studies the principle of operation of the product and its components, meeting the requirements of the tactical-technical task (TTT).
- Compiles the necessary principle diagrams of the product building components and determines the dependence between the electrical or mechanical connections in them.
- Analyses the design of the product, its technology and the extent to which it complies with the operating conditions.
- Assesses to what extent the approved design characteristics provide the possibility of creating unification and improvement of the products.
- Confirms meeting the technical requirements and economic indicators defined in the TTT.
- Makes assessment of the possibility of meeting the requirements of reliability and operability tested in TTT.
- Finalizes the technical tasks and requests for the development of new assembled units, components and materials.
- Evaluates the possibility of transportation, storage and installation of the product at the place of operation.

A program and a methodology for conducting the tests of the samples are developed in accordance with the regulatory documents defined as the basis for proving the reliability of the product [9].

A batch of experimental physical models (samples) is produced for testing in a certified laboratory. They are submitted to the laboratory and are approved, designed and built (in the necessary amount) so that their compliance with the requirements laid down in the TTT of the product can be confirmed. To conduct the tests, the presented physical models must fully correspond and repeat the characteristics of the object being tested. An analysis of the test results is prepared, on its basis it is possible to refine and correct the working project in accordance with the final decisions. This stage is related to experimenting and defining the main characteristics of the product to determine its reliability. It is seen as an initial period of development, during which the intensity of failures is increased due to the appearance of hidden manufacturing and other defects; it is also called the ‘defect period’ or ‘development period’.

An initial analysis of the test results is performed, a list of the tests carried out with the components is prepared, and the compilation of operational documentation is started. The analysis of the results is the basis for planning the necessary technological equipment and materials for the production of an experimental sample of the product. The possibilities of the research laboratory for conducting tests are checked, and a request is prepared for the necessary technical equipment and the hours for working with it.

The laboratory provides information on its certificates and metrological documentation for the test equipment.

c) *Construction of a testing sample of the product and a testing batch of the materials*

This stage is related to determining the characteristics of the materials used or the components of the product. In it, the construction of the physical models (experimental samples) of primary electrochemical power sources is carried out for conducting initial tests regarding their operability and reliability [10]. The constructed power sources are of the modern electrochemical type. One of the possibilities for improving a defence product is associated with them – non-contact radio proximity fuse (VN-RL-82) [11].

With the development of the experimental sample (physical model) and conducting tests with it, the aim is to:

- detect and remove design errors and/or deficiencies of the product and its components made in an earlier period;
- detect technological deficiencies in the construction of the elements that make up the product and to reduce failures caused by design errors;
- specify the design of the components (elements) of the product, for which no final decision was made in the previous stages;
- specify the necessary technological equipment for conducting the laboratory tests;
- specify the methods of control (tests, analysis, measurements), the means of measurement, the place for carrying out the control activities, the incoming control, etc.

On the basis of the prepared and approved working project and analysis of the results of the primary tests of the samples, the development of the initial construction documentation for the construction of the physical models (a series of experimental samples) of the product is started.

The production of the experimental sample (physical model) is controlled and performed in accordance with the technical requirements of the contracting authority and the approved tactical-technical requirements for the product. Before they are submitted for testing in the laboratory, the physical models (experimental samples) and their documentation are checked. The readiness of the physical models for conducting laboratory tests with them is controlled. A working meeting between all interested parties is agreed and carried out, at which construction, technological and operational documentation of the physical models is additionally discussed [12]. It is checked whether they correspond to the working design documentation presented in the preliminary tests and whether any changes have been made to it. The compliance of the materials used with those provided for in the documentation is taken into account as well as whether precautionary measures have been taken to reduce the risk of accidents with the experimental samples.

The results of the inspection are recorded. In the prepared protocol, proposals are made for the necessary changes and additions to the documentation, and an assessment is given of the readiness of the physical models (experimental samples) for conducting tests.

Product reliability indicators are evaluated based on the results of initial tests. It is important to determine in advance the order of collecting statistical information about the reliability of the product and its components under different operating modes and the order of evaluating the reliability indicators. The resulting statistics provide quantitative information on reliability indicators.

Physical models (test samples) that are fully completed, meet the requirements of the working construction documentation and the safety measures during the tests are approved for initial testing.

The following are submitted to the approval committee for the assessment of readiness for physical model testing:

- protocol of the committee for checking the readiness for conducting tests;
- test samples assembled according to the prepared methodology for conducting tests;
- documentation corrected according to the results of the test sample readiness check;
- program and methodology for conducting laboratory tests.

Based on the results of the conducted tests, the approval committee evaluates the compliance of the physical models (experimental samples) with the tactical-technical task and gives a conclusion regarding its operability and suitability. During the laboratory tests, in order to specify some characteristics of the product (experimental sample), by decision of the chairman of the committee, additional tests could be conducted, and control checks (measurements) of assembled units and components could be performed. Control of the characteristics and operating modes of the components of the product is carried out. The results of the laboratory tests and the approval of the trial samples are described in a protocol.

d) *Production of a testing batch of the product and a testing batch of the materials used*

The design, technological and organizational preparation, and the material-technical and metrological provision for serial (mass) production are evaluated by a committee of the manufacturer with the participation of representatives of the contractor and the contracting authority.

The products of the experimental batch and their components are approved by an approval committee with a chairman appointed by the contracting authority. The committee includes representatives of the contracting authority, the manufacturer and the contractor.

Before submitting the experimental batch for approval by the contracting authority, a manufacturer's committee with the participation of the contractor checks:

- the readiness of the products from the experimental batch and the educational and the technical means for their submission for approval tests, including tests of the products in sufficient volume;

- the working design, technological, operational and repair documentation, the condition of the originals and their suitability for multiplication;
- do the products of the experimental batch correspond to the working design documentation;
- the assembled units and the components of all operations in the process of their production to comply with the design documentation and technological processes;
- do the materials used correspond to those provided for in the documentation and the admitted discarding is analysed;
- the manufacturer's technological readiness for serial production.

The approval, periodical and type tests of products from the serial (mass) production are organized and conducted by the manufacturer with the participation of a representative of the contracting authority.

Reliability tests in serial (mass) production are part of periodic and type tests and are conducted at the request of the contracting authority in accordance with the current standardization documents or according to a methodology proposed by the manufacturer and approved by the contracting authority.

E. Modelling of physical objects and modern methods for their presentation

Modelling is a complex process by which various objects and their characteristics can be represented. Modern scientific and technical achievements make it possible to build adequate visual models that present the studied object from different points of view and facilitate its spatial study.

a) Construction of physical models of a defence product

The construction of the physical samples of a defence product (fuse) in its essence is a modelling process, which is the creation of models of existing objects.

For the purposes of the conducted research, the real object (non-contact radio proximity fuse) is replaced with suitable copies. Establishing the characteristics of the studied object of knowledge is carried out by conducting tests with its physically identical models (samples).

Different aspects of object modelling (non-contact radio proximity fuse, defence industry product, etc.) can be its appearance and structure, respectively, as well as all possible combinations of these. In the modelling process, each of the objects is revealed by a set of properties belonging to it. The properties that can be expressed with numerical values are called model parameters.

Appearance means a set of signs that characterize the appearance of the studied object. Identification is used as well as storing the image of the object.

The *structure* of the studied object expresses the set of elements and the relationships existing between them. It is used for its visual presentation in space. Studying the properties of an object is an invariable part of its structure. Exploring and discovering meaningful relationships is part of studying object stability.

The *behaviour* of the object represents the changes in its appearance and structure when interaction with external objects occurs over time. It is used for planning and predicting connection with other objects and discovering causal relationships.

The process of modelling is related to the study of an actual object by creating a model reflecting its characteristics and features. In its essence, the process is theoretical and cognitive. It is carried out on the basis of abstract-logical thinking, with the aim of researching and getting to know the object as a whole or some of its characteristics. These characteristics should be considered as copying and/or combined into one system, especially when the prototype under study is large in size or complex (made up of many components). The model can be built, tested and modified at relatively low cost compared to the actual object. Appropriately developed objects (prototypes) provide research results to be used with a high degree of confidence.

For the purposes of the research, modelling of the components (without the explosive circuit) of a radio proximity fuse was carried out in order to study an actual object. The created models reflect the characteristics and features of the studied object with the necessary accuracy to satisfy the requirements for conducting an experiment.

Fig. 2 Physical model of a defence industry product

The experiment is theoretical and cognitive and reflects the impact of environmental influences on the reliability and operability of the parts of the researched object (radio proximity fuse). The overall process related to the presentation of the characteristics of the studied object is carried out through abstract-logical thinking, with the aim of researching and getting to know the actual object, be it in its entirety or some of its aspects, characteristics and properties.

b) Construction of a 3D model of a component of a defence product

The software Autodesk 3ds MAX 2015 was used for the realization of the visual model. Several of the objects are of the Standard Primitives type, which allows direct and accurate setting of the required size during their construction. The objects are created in 1:1 scale. The primitives used to create the 3D scene are: a cylinder and a cylinder with bevelled edges. For the rest of the objects, a vector profile of the element and the function of the program Extrude were used. The materiality of the objects was achieved using the Standard material, which is contained in the built-in Material Editor module of the Autodesk 3DS MAX 2015 software [13].

The visualization of the final images was created using the built-in visualization module of the Autodesk 3DS MAX 2015 software – Default Scanline Renderer. The resolution of the images is 2000 by 1800 pixels per inch (2.54 cm), which makes them suitable for processing and pre-printing (de-scaling) of relatively large sizes.

The three-dimensional scene in which the objects are created allows the generation of images and animated frames from different angles. The prepared visual models can be moved in space and viewed from a different angle, which gives a visual idea of the object being developed.

The preliminary study made allows the use of computer programs for the virtual representation of objects in three-dimensional space in the form of models. The need to visualize the internal structure of the constructed power source models can be considered as part of their presentation. Visual models are defined as an invariable part of the developed physical models and serve for their characterization. The desired result is related to the fact that the objects used are small-sized and through the visual model their three-dimensional, proportionally identical analogues are obtained, which will allow for the evaluation of their reliability.

Visual models contribute to the solution of the construction task and to the correct design of the building elements, the rigid connections, and the position of the wires. They are the initial basis for designing the real object.

The concept project is related to the construction of a visualization for presentation of the elements in 3D space for viewing the details and their placement in the defined volume. Fig. 3 shows a visualization of a power source made up of eight electrochemical elements.

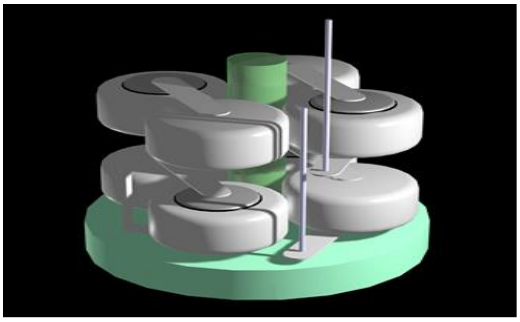

Fig. 3. Visual 3D model of a power source built with eight elements arranged on two levels

In fig. 4, based on the capabilities of the used software, a cylinder with bevelled edges is built. It represents the outer shell of the encapsulated sample. The used Autodesk 3DS MAX 2015 software provides an opportunity to preserve the spatial arrangement of the electrochemical elements in the power source.

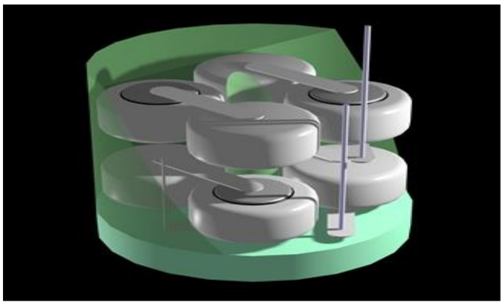

Fig. 4. Visual 3D model of the tested power source, a cylinder with bevelled edges with eight elements

The requirement set by the tactical-technical specification for a nominal voltage of 12 V can also be achieved by using a different type and size of the electrochemical elements. Power sources with CR-1/3N electrochemical (lithium) elements have been developed and tested. Fig. 5 presents the prepared visual model of a power source consisting of four elements.

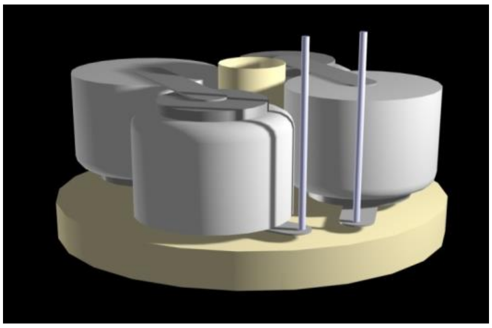

Fig. 5. Visual 3D model of a power source built with four lithium elements

The use of fewer elements in the power source leads to an increase in its reliability, due to a decrease in the probability of failure of parts or errors from improper connection.

IV. CONCLUSIONS

The development and implementation of a scientific research plan for the improvement of a product intended for the defence industry begins with a study of the type and characteristics of the product. The main stages in the implementation of the research task are logically justified and pre-approved. A Plan for the design, manufacture and testing of physical samples of a defence industry product Plan for the construction, development and testing of physical samples of a non-contact radio proximity fuse (VN-RL-82) is prepared. It tracks and describes the sequence of activities related to the implementation of the main stages of the research for each product individually. It presents the conceptual and working project of the research and the main points of the research task. The construction, an experimental batch of materials and an experimental series of physical models of a non-contact radio proximity fuse are described. Through the proposed plan, testing of operability and reliability of the power source is to be conducted.

The created physical models reflect the characteristics and features of the studied object with the necessary accuracy to meet the requirements for conducting an experiment. The practical-application process related to the presentation of the characteristics of the studied object is carried out through abstract-logical thinking, with the aim of researching and getting to know the actual object, be it in its entirety or some of its aspects, characteristics and properties.

A series of figures describe the construction of a visual 3D model of the power source. The Autodesk 3ds MAX 2015 software was used for its implementation. Several of the objects are of the Standard Primitives type, which allows direct and accurate setting of the required size during their construction. The objects are created on a scale of 1:1. The obtained results clearly represent the possibility of using visual programs in the representation of objects with a complex internal structure. The use of object visualization programs is a modern and applicable method for representing the internal structure of physical models (objects). The constructed visual 3D models allow for viewing the power source of a non-contact radio proximity fuse in three-dimensional space, the possibility of finding and correcting design errors, and visualization of the final product.

V. ACKNOWLEDGEMENTS

The paper was financed by the National Scientific Program 'Security and Defence' of the Ministry of Education and Science of the Republic of Bulgaria, in implementation of the Decision of the Council of Ministers of the Republic of Bulgaria № 731/21.10.2021 and under Agreement № D01-74/19.05.2022. Work task 3.1.1. Research and application, in the field of security and defence, of renewable and chemical sources of electricity and the possibilities of using non-volatile sources based on lithium.

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