APPLYING OF THE SYSTEMATIC APPROACH FOR THE CANNON BARRELS DESIGN

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Abstract: *The report scrutinizes the possibility of applying the systematic approach for designing the barrel of an artillery system.*

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The changing of the character of combat action necessitates a constant searching for new qualitative opportunities for the creation of complexes of weapons having higher performance indicators. To achieve this, a detailed analysis of the conditions of their operation, optimization of the composition and characteristics of all subsystems is required based on an objectively chosen, physically measurable criterion. Performing a detailed analysis of the weapons complex of a self-propelled artillery or towed artillery system is inconceivable without a systemic approach. [2]

In the designing of artillery systems, it is particularly important to be justified the structure of the armament complex on the basis of new technical solutions for its elements and the system as a whole. Of particular importance is the determination of a rational combination of the complex parameters, which ensures the joint fulfillment of three requirements: sufficiency of the striking action of the ammunitions, easy exploitation and high efficiency of the armament.

When it is applied the system approach to solving the problem, the properties of the combat machine can be represented as a structural scheme. At the top level of the structure, there are four basic properties: firepower, security, mobility and the totality of operational and technical capabilities. In each of the abovementioned properties there are internal properties that can also have their own structure. Depending on the goals pursued, the division of the structure of properties can be at several levels (usually a maximum of 6 ÷ 7) [8].

The barrel is part of the artillery system designed to guide the projectile's motion when shot and to deliver his necessary speed. The construction of the barrel largely determines the combat qualities of the weapon complex as a whole. The barrel is designed based on a chosen ballistic solution and of its construction in a large extent depends the structures of the other elements of the weapon system.

The design of the cannon barrel is a logically connected set of constructive methods, ensuring the obtaining of a working structure that satisfies the specific requirements imposed on the barrels. It is necessary that the design to be preceded by an analysis of the requirements imposed on its construction, the study of existing structures of artillery barrels and their peculiarities.

The general requirements that must be met by the construction of the cannon barrel derive from the analysis of several subsystems of a different type in which the barrel is an element. The type of these subsystems depends on the type of the designed artillery complex. Performing a system analysis provides the opportunity to formulate a private technical assignment (PTA) required for the design of a weapon barrel. The same should contain all the necessary requirements and output data for the cannon barrel structure.

It is advisable to perform the system analysis in the following order:

1. The barrel is considered as an element of the ballistic system "barrel-charge-projectile" which provides the required initial velocity of a projectile with a given caliber and mass. Completing the ballistic design of the cannon barrel gives clarity for the barrel channel construction data, charging conditions, and ballistic characteristics of the shot.

Because the internal ballistic process is characterized by particularly high power and thermal stresses of the barrel and with high dynamics and cyclic repeatability, the first requirement in the design of cannon barrel is to provide the necessary strength. This can be done using design techniques that take into account the actual barrel functioning conditions in the “barrel-charge-projectile” system. The requirements for strength of the cannon barrel can largely be satisfied by using of special steel. They provide barrel resistance against the effects of chemical products from the incineration of the charge and combine both hardness and elasticity.

2. The rear barrel portion is viewed as a part of the channel closure node, whereby requirements related to the reliability of the closure node may be set. The rear part of the barrel must have increased strength, especially at the spot where is connected with channel closure node, in order to be ensured reliable obturation of the gunpowder gasses and undertaking the strength effort of the shot.

3. The barrel is presented as the primary element of the cannon. In this case, the barrel must have a mass that provides acceptable dynamic characteristics. In the early stages of design, this can be determined by the speed of free recoil of the prototype guns. Additionally, the barrel must have a certain length according with the accepted length of the recoil. Additionally, barrel expansion caused by pressure and temperature should not result in its wedging in the cradle.

4. Consider the barrel as an element of the rising and rotating parts of the artillery system. In this case, the barrel must have an acceptable mass and rational positioning of the center of the mass relative to the axes. This will provide acceptable inertial characteristics of the movable parts and optimal characteristics of the directing mechanisms and the balancing and stabilizing mechanisms.

5. The barrel is regarded as the primary functional element of the artillery system, which it is the element of the weaponry system, which includes the artillery system, the ammunition, the vehicle, the fire control devices, etc. The barrel as part of the complex is assigned a great deal of tasks related to the accuracy of the shooting. Keeping the accuracy of the shooting when it is given a specified number of shots set in the Technical Specification depends largely on the barrel design and its resistance to wear. Taking account of these considerations, the construction of the barrel's leading barrel part must meet the requirements for reliable stabilization of the projectile and good resistance to wear.

6. The barrel is considered considering its affiliation to a specific production system. Because the cannon barrel is a very complex detail, the early stages of the design must take into account the possibilities for its manufacturing. The manufacturing system should incorporate the most economical technological means for the production, taking into account the existing equipment, technologies and production prospects.

After performing the system analysis of the subsystems to which the barrel belongs, the technical specification can be formulated. In this specification, besides the mandatory internal ballistic characteristics are included also requirements for the strength, dimensions, center of the masses and inertial characteristics, requirements for the materials used, wear and performance characteristics and other input information are included.

The general concepts of the design of cannon barrels refer not only to a barrel-monoblock but also to barrels of other types.

The construction of the barrel must be made on the basis of the private technical assignment and the requirements for modern guns. The solving of the task for designing of a cannon barrel begins with the design of the simplest barrel construction, namely: barrel-monoblock.

In the early stages of the design (conceptual design) of the barrel-monoblock the following main activities must be carried out:

1. Justification of choosing the charging method, constructing its corresponding charging chamber and carrying out the design calculations.

2. Designing the leading portion of the barrel channel including: selecting the method for guidance of the projectile in the channel; choosing the shape of the cuts and calculating the number and size of the cuts, etc.

3. Pre-selection of the external shape of the barrel and selection of material for its manufacture. Here must be noted the joining of the barrel with the closure node, the presence of additional devices, the way of guiding the barrel in the cradle when recoiling, etc.

4. Calculations of the transverse strength of the barrel and specification of its structural dimensions. Calculating the actual mass of the barrel and the position of its center of the mass. Correcting the outer contour of the barrel to obtain the optimum mass and position of the center of the mass.

The mass of the barrel must satisfy the required free recoil speed *Vm*, which for the different types of turret is as follows:

- for powerful systems *Vm* is in the range 8 ÷ 12 m / s;
- for tank guns *Vm* is in the range 10 ÷ 15 m / s;
- for gauntlets *Vm* is in the range of 14 ÷ 20 m / s.

The resulting factual value of the barrel mass as a result of the calculations must correspond to the desired free recoil speed. This is not strictly determined, and if the actual mass of the barrel is diverted within ± 20%, it is assumed that the barrel design is satisfactory with respect to the mass. Otherwise, a mass adjustment is made by changing the construction, dimensions or material.

5. Final determination of the dimensions of the barrel and verification of the transversal strength after correction of the dimensions.

The calculations for barrel warm-up, the wear estimate and the duration of its operation are usually performed at the design stage.

The specified design tasks are logically arranged, each previous task having a multivariate solution, and the end result impose some limitations on the next solution if a system approach is applied. Thus, the options for solving each subsequent task are limited. Because it is a long process it is logically to look for a way to reduce and facilitate it. This necessitates the use of databases obtained experimentally or borrowed from the design processes of already existing artillery systems. The acquisition or creation of such types of databases allows a high degree of automation of the design process, which will inevitably lead for reducing design time and the process efficiency.

The creating a Cannon Barrel Design Automatized System (CBDAS) will greatly facilitate the designer to review multiple variants and accept a technically grounded barrel design solution. Such a system, having a rich database and working in dialogue with the designer, will ensure that you would get a quality project on a contemporary level. The question of the efficiency of the project and the correctness of the decisions taken will be decided in the course of the artillery system testing.

If a Cannon Barrel Design Automatized System has been created, it could allow automated execution only of a part of the process such as a project solution for the artillery barrel. A project solution means a barrel construction that is needed in the early stages of design. Essentially, this is a complete set of structural parameters of the barrel (shape characteristics, dimensions, kind of steel, tolerances, etc.) and its functional parameters (mass-center characteristics, strength indicators, etc.).

This set of parameters allows you to move on to the implementation of the working technical documentation of the barrel (development of a working draft).

The above describes the concept of "project procedure". This is a set of user actions in the automatized design system, the completion of which ends with a cannon barrel design solution. The design process can be presented as a set of such project operations whose algorithm remains unchanged. Separation of the project design procedure is conditional because to it reflects current standards and designing techniques. In principle, the design procedure should include a list of operations and the sequence of their execution, the possibility for the user to participate in its work, the availability of a design assignment and a description of the design object.

The above mentioned specificity of the task for cannon barrel design as a procedure confirms the need necessity in the center of the process to be placed the designer, actively interacting with the automated design program. Only the dialogue mode for the design process can provide the user with:

• introducing a variety of input information needed for the whole project process and for individual project operations;
• obtaining instructions during the system operation;
• possibility to discontinue the design process for ancillary activities at a suitable time;
• the ability to switch from one design operation to another if it does not violate the design logic;
• the ability of the designer to respond adequately to messages made by the system and to receive assistance under its operating rules;
• the possibility of completing the dialogue after achieving satisfactory results.

The information providing for the design of a cannon barrel is a set of knowledge needed to perform an automated barrel design (ABD) and their presentation in a given structure. The information need is a set of requests for information necessary for the design of the cannon barrel. The same is the basis for providing information on automated barrel design. The following data bases are required to perform the information support required for the design of a artillery barrel:

• a private technical assignment for the barrel as an element of the general technical specification for the weapon system;

• data obtained from previous design steps or other procedures in the automated design system (in this case ballistic design);

• reference data, which are usually separated into separate information and reporting system (IRS);

• data about the components of the barrel information model;

• user data.

The listed data variants and their interaction with the software for the automated design of the barrel and the users are indicated in the structural diagram of Fig. 1.

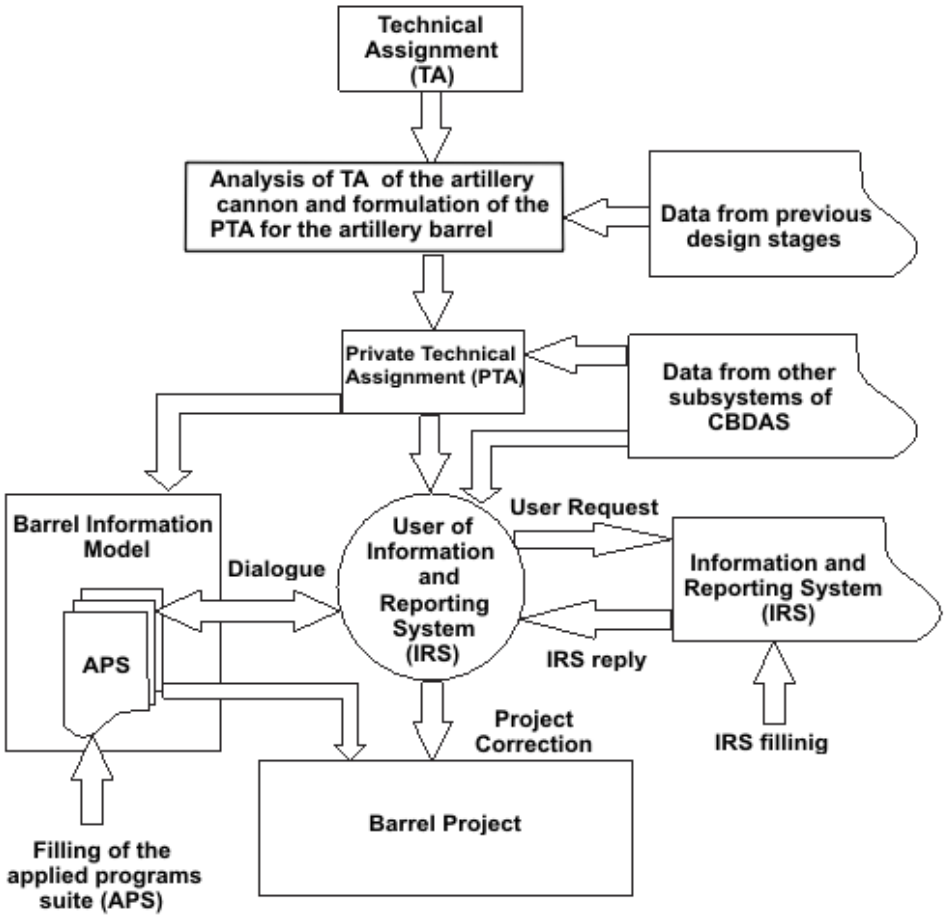

Fig. 1. Structure diagram of the information and programming providing of the system for the automated design of the artillery barrel.

The information system consists of information that enables the user to fully intervene in the process of automated design, to correct and direct it in the required direction. The scope and reliability of data in the information system extends the user's capabilities, positively influences the quality of design solutions and reduces design time for the design.

The information system of the barrel design process includes the following information blocks:

• state standards, standards of the design organization, norms, technical requirements and other data regulating the construction, materials, tolerances, assemblies, etc .;

• information for the construction-ballistic and functional characteristics of barrels from existing weapon systems;

• information for the strength, hardness, heating, wear and life of the barrels, cooling efficiency, and so on;

• information for the aggregates and objects related to the barrel constructively and functionally (ammunitions, bolts, muzzle brakes, etc.);

• information of a technological nature reflecting the achievements in the development of barrel technologies;

• information of a technical and economic nature: design costs, development of existing systems, price references for materials, etc.

The final product resulting from the user's work with the database can be presented in the form of tables with data for the barrel and drafts.

An important feature of any Information - Computing System (ICS) is the degree of its informational commitment to the environment. The Information - Computing System must be dynamic and continually use information about the changing the environment beyond the design system. In this sense, the cannon barrel design subsystem must be open and fit for improvement.

Sectoral software is presented in the automated barrel design through an applied programs suite (APS) (Fig. 1). For convenience, two types of modules (programs) must be designed in the application packages package: for designing and for control.

The modules for designing use input information at their entrance and give on their output the needed constructive parameters: type of construction, shape characteristics, dimensions, required characteristics, brand of materials, etc. In order to be solved the question of the composition of the designing module package, it is necessary to be modeled the process and to be constructed the sequence of operations.

The modules for control receive on their entrance initial information as well as information obtained in the design modules and give on their output the functional performance characteristics of the structure: strengths reserves, deformations, heating temperatures, wear indicators, frequency the oscillations, etc. For the determination of the composition of the modules for control, it is necessary to consider the conditions for the creatability of the guns.

The analysis of the processes occurring in the cannon barrel allows to be separated on several groups of parameters necessary to form a package checking programs. The main sets of parameters needed for this are:

- parameters characterizing the total transverse and longitudinal strength of the barrel and its details;
- parameters characterizing the shape, dimensions, and condition of the surface of the barrel channel;
- parameters characterizing the barrel as a mechanical oscillating system;
- parameters characterizing the barrel as an integral part of the weapon system.

The heretofore was demonstrated that the theory of cannon barrel design continues to develop on the basis of the deeper understanding of the physical processes taking place in the barrel during shooting and the more accurate modeling.

Applying a systemic approach to the complex process of barrel design, as a weapon complex subsystem, allows the continuous improvement of the process, shortening the design time and the realization of artillery models with high combat qualities.

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