ANALYSIS OF THE FACTORS AFFECTING THE THERMOPHYSICAL STATE OF A SMALL-CALIBER ARTILLERY BARREL

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Abstract
This article analyzes the factors affecting the thermophysical state of the barrel of small-caliber aviation artillery weapons (AAW), and provides the main achievements and shortcomings of factors affecting heat resistance, and the prospects for their development indicated.

Keywords: Aviation artillery weapons, aircraft, stability and barrel strength, main characteristics, heat resistance.

Introduction

Despite the difference in the design schemes of aviation artillery weapons (AAO), one of the most critical elements of small-caliber rapid-fire guns, operating at high temperatures and experiencing high thermophysical loads, is the artillery barrel (hereinafter referred to as the barrel). intraballistic conditions of projectile guidance, barrel survivability, and air firing safety are inextricably linked with the objective need to study the temperature field and, as a result, to reveal the impact of various factors on the quality of the barrel functioning of actions in time and space.

The reasons for the violation of the standard conditions of the barrel operation are, as a rule, various kinds of defects - each individual non-compliance of the product with the established requirements. A complete failure that puts the barrel into the limiting state can occur as a result of the presence of one or more defects, but the appearance of a defect does not always lead to failure. We interpret a defect as a certain flaw (defect) of the product, which is the result of the impact of design, technological, energy, external factors, as well as a subjective factor associated with scientific, technical and operating personnel.

Relevance and statement of the problem. The influence of design and technological factors is determined by the state of fundamental theoretical knowledge that is the basis for the design, production and operation of AAO, the degree of generalization of the experience of similar developments, theoretical provisions and scientific achievements of related technical areas, the quality of raw materials, the perfection of technology and equipment for the design, production, and operation of AAO.

It should be noted that an important design factor is the continuous growth of requirements for expanding the range of AAO applications. At the same time, there is a significant transfer of

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reliability problems from the field of circuit engineering to the field of design. For example, ensuring the optimal modes of operation of AAO becomes an extremely difficult problem due to the inaccessibility for adjustment from the outside and can be achieved only through accurate calculation of geometric dimensions and physical parameters of active structures and their implementation during manufacture. Minimal regulation of the modes of operation of rapid-fire assault rifles is partially possible solely due to the variation of firing modes and the subsequent removal of heat from the barrel.

Typical and non-trivial approaches to solving the problem. We do not aim to substantiate the possibility of improving the design characteristics of AAO, testifying to its structural perfection.

Energy factors include various types of energy that affect the properties of the barrel. These effects can be both known and accidental, leading to deviations in parameters.

When analyzing the impact of chemical energy in the form of corrosive media , we will proceed from the fact that the powders used to equip unitary cartridges for AAO, according to their chemical elementary composition, are compounds of carbon, hydrogen, oxygen, nitrogen with a content of intramolecular oxygen sufficient for the complete transformation of combustible elements into powder gas (hereinafter referred to as gas).

Powder combustion occurs first in a constant (up to a forcing pressure of 30 MPa), and then in an increasing volume of the barrel bore. Therefore, during the combustion of gunpowders, mainly gaseous products are obtained, and only in some cases a very small amount of solids is formed.

Thermal energy acts on the barrels due to reaching the value of the temperature of gases, the burning temperature of gunpowder ≈ 2800 K. As studies [1] show, when exposed to gases, 12... 17% of the heat released during the combustion of the entire powder charge.

Under the influence of heated gases, the chamber and the walls of the barrel are heated. In the process of firing, the surface of the barrel washed by gases increases. An increase in the volume in which the gunpowder burns leads to a certain decrease in the combustion temperature. At the same time, the gases, imparting an ever-increasing speed to the projectile, perform work and cool. In the second period, due to adiabatic expansion, the temperature of the gases decreases even more sharply and reaches a value of six to seven tenths of the combustion temperature of the powder by the muzzle [2].

Thus, the barrel experiences rapidly changing temperature loads along the entire path of gas movement. It should be noted that when modeling and studying the dynamics of AAO functioning in thermal formulation, as a rule, the quasi-stationary hypothesis known in thermodynamics [3] is used, according to which the temperature loads on the object under study depend only on the instantaneous values of the coolant temperature, determined from the energy characteristics of the heat source.

Mechanical energy is a type of energy that is transmitted in the form of dynamic loads during the movement of the projectile in the barrel. These loads lead to the action of friction forces in the barrel bore, deformation of the groove edges, violation of the conditions of projectile guidance in the barrel, and other undesirable phenomena.

The powerful impact of the projectile on the channel leads to additional heating of the barrel. When using copper driving belts, the average friction temperature is calculated using an empirical formula that takes into account the current speed of the projectile (gases) in terms of coordinates and time [4].

It has been established that the impact of the projectile driving device on the surface of the barrel bore is a short-term thermal impulse with an almost instantaneous rise front compared to the time of exposure to gases. The amount of heat from the mechanical impact of the projectile driving device during its movement is variable along the length of the barrel and amounts to 12... 20% of the total heat entering the barrel during the shot [1]. Thus, the barrel heats up to a greater extent from the impact of gases than from friction.

The value of the steady temperature in the barrel sections in this case will depend on various factors and, first of all, on the rate of fire the temperature of the trunk, especially the inner walls, rises to values of ≈ 1200 K.

After the projectile leaves the barrel, the gases flowing out at high velocity after the projectile, at a distance of 20... 40 calibers from the muzzle of the barrel cause its additional heating, continuing to have a thermal effect on the barrel. It should be pointed out that, as a rule, this phenomenon of intermediate ballistics is taken into account by introducing the so-called "correction factors" (for example, in the paper [4]), due to which the results of the solution are not entirely accurate.

When firing stops, but the next cartridge is sent into the chamber, the opposite process may take place - heat removal from the heated breech of the barrel to the cartridge. When the cartridge is held in the barrel, it heats up and redistributes temperatures over the chamber.

The presence of the next cartridge in the barrel heated by the previous firing is a special case of the process of using AAO, since after stopping firing in the event of reaching the maximum temperature of the barrel bore in the chamber area, the elements of the fuse equipment can heat up to the maximum temperature of spontaneous operation. Natural gradual changes in the physical structure of the "cartridge-barrel" system, which under certain conditions, they acquire an avalanche-like character, lead to the occurrence of thermal runoff as a result of local temperature fluctuations and overheating, which, accumulating, during the next thermal overload of the barrel, lead to a sudden failure with an intensive transition to the limiting state. In case of exceeding the value of the parameter determining the safety of the use of AAO the barrel rupture, the destruction of the AAO and the CAV as a whole follow, since explosive processes occur at the points of contact between the elements of the cartridge and the barrel bore. The probability of the event in question is determined by the rate of fire, the number of shots in the burst, the number of bursts of shots, and the time intervals between bursts of shots. One of the possible ways to eliminate this unpleasant phenomenon can be considered the development of a thermodynamic model of the functioning of the "cartridge-barrel" system with the introduction of safety criteria for the fire operation of the AAO with the most complete implementation of the time of firing bursts and taking into account the total number of bursts of shots in the ammunition loads of the AAO fired in normal modes.

Thus, all types of energy, affecting the barrel, cause a number of undesirable processes, create conditions for deterioration of its technical characteristics and the occurrence of failures.

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External factors include the conditions of fire operation of the AAO: the speed of the incoming air flow, decrease and increase in temperature and air pressure depending on the altitude of the AAO application, precipitation in the form of rain and snow, wind speed, as well as kinetic heating and solar radiation.

The data show [4] that among these factors, precipitation, for example, rain with an intensity of 0.05 mm/s when firing from automatic cannons with a caliber of up to 30 mm, has the greatest impact on the preservation of normal firing conditions. the temperature field of AAO barrels in comparison with long thin-walled barrels for tank and anti-tank guns. Based on the conditions of air firing, the wind speed is incomparably small in relation to the speed of the incoming air flow. With subsonic speeds of use, comfortable (intra-fuselage) placement of the AAO and a barrel closed from the rear end, the kinetic heating of the system is very insignificant.

Accounting for such disturbances seems to be a very difficult problem. The action of these components, as a rule, is not constant. Moreover, disturbances of this nature do not have a noticeable effect on the formation of the barrel temperature profile and may not be considered. The intensity of heat exchange between the barrel and other elements of the AAO structure is very small (less than 1%), does not have a significant effect on the formation of the barrel temperature field, and, therefore, may not be taken into account and also not taken into account in the model.

At the stages of formation of technical requirements, development and testing of AAO, the erudition, qualification and talent of developers and researchers largely predetermined the success of the extremely complex business of creating barrels with the necessary reliable properties [5, 6]. In this regard, the solution of the issue of choosing rational parameters of thermoplastic shaft loading can be considered one of the priority areas for ensuring the standard conditions for the use of AAO.

The production and operational processes of the AAO, where many different highly qualified specialists are also employed, have overwhelmingly confirmed the optimality of compromise design solutions found in mutually exclusive situations, which, however, does not exclude the possibility of improving the quality of the AAO functioning on the basis of modern achievements of science and technology.

Timeliness and quality of maintenance at the stage of technical operation of barrels are established as indisputable initial data. The intensity of flight operation of the barrel depends on the length of each burst, the number of bursts and the time of the break between bursts of shots. As a basis for varying the number of shots in a burst and bursts of shots, we will take the standard modes of fire operation of AAOs specific to the automatic control systems of aircraft guns. There are currently no rules that have priority in the selection of the studied time intervals between bursts of shots. knowledge of applied issues of the subject area. The minimum duration of breaks between bursts of shots will be chosen, taking into account the combination of the moments of time for the crew to evaluate the results of the previous firing and re-aiming while piloting the aircraft, which, based on the methods of using AAO for the most trained crews, is at least 3 seconds.

Based on the analysis, the organization of promising research paths concerning the factors of influence affecting changes in the trunk temperature profile is possible on the development of the direction of reliability, which naturally includes the description of transitions in objects and the interaction of objects with the environment as a multifactorial process. Modern methods of developing the foundations of the parametric theory of reliability [7, 8] are essentially attempts to introduce into deterministic calculations the analysis of a complex of phenomena that lead to changes in the states and properties of objects and, ultimately, to failures.

At the same time, a distinctive feature of the objects that serve as an application of the system (physical) theory of reliability is that the conditions of their operation are relatively homogeneous, quasi-stationary and can be reproduced under the conditions of statistical tests. The theory of physical reliability, developed in great detail [9], assumes that probabilistic tools in the form of typical generalized and partial operators are sufficiently adapted to solving engineering problems.

Conclusions

The analysis of the factors is aimed at the typology of impacts that are of dominant importance in the formation of a mathematical model of non-stationary heat transfer processes in the shaft and the organization of the procedure for assessing the quality of AAO application. It is important to further solve the issue related to the definition of a unified methodological approach and the selection of an appropriate apparatus, within the framework of which the problem of improving the existing modes of fire operation of AAO is solved.

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