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THE INFLUENCE OF THE BARREL ON THE DURATION OF INFANTRY ARMAMENT. FACTORS INFLUENCING THE SERVICE LIFE OF INFANTRY GUN BARRELS

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ABSTRACT

In general, the service life of a system is determined by its technical characteristics, the nature and magnitude of the stresses to which parts are subjected and the operating, operation and maintenance conditions. For this reason, the article aims to outline the key issues that highlight the factors influencing the service life of infantry weapons and how they do so. The essential elements are pointed out and the influence of each factor in increasing service life is presented, first by component sub-assemblies and then for the armament as a whole.

KEYWORDS:

Service life, construction of the barrel, construction of the bullet, composition of the propelling charge, cooling and operating capacity of the barrel, technical resource, critical technical condition, critical value of the resource

1. General considerations

In general, the service life of a system is determined by its technical characteristics, the nature and magnitude of the stresses to which parts are subjected and the operating, operation and maintenance conditions.

In terms of infantry weapons, parts and mechanisms are subject to different stresses, which also lead to different degradation and wear. The normal service life of the armament is given by the life of the barrel which is expressed in the number of shots fired until the initial velocity of the bullet (shell) decreases by more than 5% and the spread exceeds 8 times the value specified in the firing table (Keresztes, 1999).

Wear and tear on the inside of the barrels used for firing is the destructive consequence of the processes that take place during these actions.

Examination of the inside of the barrels of weapons removed from service after firing reveals the following wear patterns:

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● physical wear of the barrel's channel, which causes the grooves to be worn – especially the fittings, makes the inside of the barrel show noticeable dimensional changes and changes in the geometry of the barrel's channel;

● shallow cracks and fissures, which typically form a network, particularly in the back side of the groove and which decrease towards the muzzle, both in density and depth;

● shallow and sometimes deep fusions, especially at large-caliber infantry weapons. These sometimes extend in the form of more deep grooves on the surface of which the effects of fusions sustained by the metal during firing are visible.

The three groups of phenomena, which cause physical damage to the interior of the barrel, occur in most cases simultaneously, influencing each other, but depending on the stress on the barrel, one aspect or another predominates at a given time of the ballistic life.

2. Influence of the barrel on the service life of infantry weapons

The technical resource of infantry weapons is given by the calendar duration of operation until reaching critical technical status or until scrapping (reforming).

The critical technical status of infantry weapons corresponds to the situation where they no longer achieve the designed technical parameters during operation and training and the safety and security of personnel during firing is compromised.

Infantry weapons are made up of a multitude of parts, which are constructively and functionally different.

Basically, for an infantry weapon to be able to realize its technical resource, it is particularly important to establish (determine) the optimal resource sizes of the component sub-assemblies and the ratio of these resources to the weapon resource (Popescu, 2015).

Each part (reference) is given the resource up to the critical state, denoted by r_{cr}.

The critical technical state of the part is that technical state in which it can no longer perform its functions and refurbishment is either technically impossible or economically unreasonable.

The technical resource of the barrel is defined by the number of fires shot until the critical technical state of the barrel is reached, i.e. that state which makes it impossible to recondition it.

As the barrel is the most required and important part, if it wears out, replacing it with a new one is not economically justifiable, which is why the weapon in question is withdrawn from use. The other parts of the automatic weapon, when worn out, can be replaced or reconditioned during operation.

The life of the barrel is influenced by several factors and they differ according to the category of weapon (Table no. 1).

The values given in the table are average values, so they may be higher or lower depending on the factors influencing barrel wear. The most important factor that can lead to barrel degradation is the firing conditions, which, in the case of infantry weapons, can shorten their life by up to 3000 rounds or increase it by up to 50 000 rounds.

Table no. 1

Barrel life by weapon category

Weapons category	Barrel life [no. of rounds]
Infantry weapons	10000-30000
Smooth-bore weapons	50-1500
Artillery armament with rifled barrel	500-7000

If firing is done in short series or fire by fire, the barrel has enough time to cool down, so the influence of temperature on wear will be greatly reduced. Using a continuous firing regime, especially in machine guns, the barrel can heat up to 500-700 °C, thus promoting premature wear of the barrel's interior.

Analysis of the surface of the interior of decommissioned gun barrels, following normal operation, reveals the presence of surface erosion along the entire length of the groove and in particular the fittings. Over time, this erosion leads to an increase in caliber, a decrease in the height of the fittings and an increase in the roughness of the surface, which causes the bullet to be guided incorrectly, increases friction and reduces accuracy.

The wear of the inside of the barrel is not uniform along its length, being more pronounced in the first half and near the muzzle.

Erosion occurs in the form of fine networks of cracks, both transversely and longitudinally, which are masked (covered) by deposits of material from the bullet jacket. In order to reveal the phenomenon, it is necessary to dissolve these deposits using reagents.

When the wear exceeds the maximum functionally permissible values, the barrel resource reaches the critical value, r_{cr}. Practically, the subassembly can no longer be reconditioned and must be taken out of service. Thus, a barrel that has reached its critical resource level can no longer be used for firing.

The technical resource of infantry weapons is dependent on the resource of the barrel, which in turn is influenced by the number of rounds fired with it.

If the lifetime of the weapon, represented by the average number of rounds fired with it, coincides with the lifetime of the barrel, when the critical value of the barrel resource, r_{cr}, is reached, the weapon also reaches its critical resource value, denoted by R_{cr}, the weapon is classified as impossible to be refurbished, so $r_{barrel} = r_{cr.\ barrel}$ .and $R_{weapon} = R_{cr}$.

In other words, the service life of infantry weapons, materialized by the resource supply is maintained as long as the critical barrel condition has not been reached.

In the extended version, a broader analysis is made, in which the influence of other main subsets in the evaluation of the technical resource level of infantry armament is also discussed.

3. Factors influencing the life of infantry gun barrels

Factors that influence pipe life are:

- barrel construction;
- bullet construction;
- the composition of the shot charge;
- cooling and serviceability of the barrel.

Barrel construction

The construction of the barrel influences its life through caliber, wall thickness, interior construction, material composition and manufacturing technology.

The thickness of the barrel's walls influences the amount of heat taken up from the gas and its transmission by conduction into the metal mass and by radiation into the atmosphere. The higher the cooling rate, the longer the life of the barrel because the temperature of the inner layer equalizes faster and the thermal action of the gases is shorter. The heating of the barrel's material changes mechanical characteristics such as elasticity, yield strength and Poisson's ratio to a significant extent.

With each shot fired, the barrel gains a certain amount of heat which is greater the higher the gas temperature and the greater the amount of gas exchanging heat. In the breaks between the firing (rounds), temperature equalization takes place due to the thermal conductivity of the barrel. Of the total heat input, part is transmitted to the outside environment via radiation and the rest causes the barrel temperature to rise.

The temperature that will be reached depends on the firing rate (velocity), the contact surface of the barrel with the air and the heat transfer coefficient, by radiation, to the outside environment. The amount of heat released to the environment depends on the size, shape and condition of the

surface of the barrel and in particular the external environment. The most effective cooling is with water because at a temperature difference of about 100 ^{o}C between the temperature of the barrel and the environment, water can take up 200 times more heat than non-channeled air. Since water cooling cannot be adapted to hand-held weapons, other cooling methods are used, such as increasing the existing surface area of the barrel, increasing the mass of the barrel, using spare barrels, etc. Therefore, heat balance will occur when the temperature of the barrel has reached the value at which the amount of heat given off to the environment between two rounds is equal to the amount of heat received at the moment of firing.

The construction of the inside of the barrel influences its life through the profile, height and lean of the grooves and the condition of the inner surface. The profile of the grooves can be rectangular, trapezoidal, rounded, etc., the best one from the point of view of manufacturing, sealing, guiding and barrel life being trapezoidal. The height of trapezoidal grooves must be within certain limits. Too great a height ensures good guidance and sealing but causes severe deformation of the bullet, making it less aerodynamic. A low height of the grooves can cause the bullet to slip from the grooves, resulting in poor guidance and sealing.

The lean of the grooves is determined by the stability of the bullet on the trajectory, which is better the higher the speed of rotation. This velocity imposes large leans of the grooves, which leads to high stress on the flanks, cracks at the base of the flanks and strong dynamic stresses when the bullet engages the grooves and exits the barrel. Therefore, from the point of view of the life of the barrel, it is better to use a barrel with as little lean as possible, possibly with progressive lean (variable pitch).

The mechanical and thermal characteristics of the barrel material depend on the composition of the steel (percentage of carbon and alloying elements), the way it is processed, the plastic and mechanical processing methods, the heat and thermo-chemical treatment conditions, etc. The barrel material must have high endurance and yield strength, good toughness and resistance to corrosion and high temperatures. Alloying elements reduce thermal conductivity, but this is compensated by superior mechanical characteristics.

Improvements in the mechanical qualities of barrels can also be achieved through manufacturing technology, from the steelmaking process to the finished product. After careful processing, the steel can be subjected to re-melting and refining processes, thus achieving a higher quality in terms of structural homogeneity and metal purity.

The technology of drilling and rifling of barrels influences the condition of the inner surface, the structure of the material and the qualities of the surface layer.

Several methods such as casting, rolling, hot or cold forging, etc. can be used to obtain the semi-finished product for further mechanical treatment, each with advantages and disadvantages. Of decisive importance in the technological manufacturing process are the interface and final heat treatment conditions to which the barrel is subjected (Vasilescu, 1997).

Another aspect that contributes to increasing the life of the barrel is the protection of its inner and outer surface, which is necessary to increase the mechanical, chemical and thermodynamic wear resistance of the interior, and to reduce the corrosion effect of the exterior caused by atmospheric agents (Rădoi, 1982).

Bullet construction

Bullet construction influences the life of the barrel through its cover material, shape, dimensions and guiding length. In order to reduce the wear of the barrel material, due to the bullet's rifled cut and friction, bimetal is used as the jacket material. It provides a good barrel seal and correct bullet guidance.

The diameter of the bullet (jacket) must be larger than the diameter of the fittings in order to seal the barrel at the front and must have well-determined values so that the bullet does not deform excessively (only its jacket) and this deformation fills the gaps in the grooves so that the gases do not leak forward.

The engagement in the grooves must be gradual, which requires that the surface of the connection between the tip of the bullet and its body is tapered. From this point of view, bullets with pointed tips are more advantageous than those with rounded tips.

The jacket material, guide surface, and bullet diameter affect firing conditions by changing the pressure as a function of the velocity of the bullet. This may be constant along the length of the barrel if it is unused, or variable if it is worn. The expansion of the barrel due to heating results in less force and guidance of the bullet, lower gas pressure, and even incomplete combustion of the powder (Vermeșan, 1981).

Proper vibration-free movement of the bullet in the barrel is determined by the shape, dimensions, and length of the guide. A long bullet length ensures good guidance, but due to the large contact area, the frictional force is high, causing increased wear.

The composition of the propelling charge

The propelling charge influences the life of the barrel through combustion temperature, combustion velocity, chemical corrosion of the gases and erosion due to gas leakage. The temperature, burning rate and composition of the gases that arise when the powder burns, depend on the nature of the powder and the charge density. Barrel life is longer if nitroguanidine-based powders are used because they have lower combustion temperatures compared to nitroglycerine-based powders. The temperature variation along the barrel is not uniform, being higher at the maximum pressure. This temperature distribution is demonstrated by the fact that the appearance of cracks and melts is more pronounced in the first third of the barrel, decreasing towards the muzzle.

The flow condition of the powder gases influences the heat exchange and thus the heating of the barrel interior. Turbulent flow favors heat transfer, producing in some areas high heating, leading to melts and blasts which further stress turbulent flow.

In well-sealed bullets, the amount of gas escaping forward is very low and the surface temperature does not reach the level that can cause local melting. The main cause of the heating of the barrel is the normal flow of gas through the whole barrel section following the bullet (Popescu, 2020).

The heat exchange effect of this leakage is greatly increased if strong swirls occur at any point. These swirls occur primarily in the area where the bullet is introduced in the barrel, which causes this area to show increased wear. Another cause of swirls is surface roughness and particle detachments, where even local shallow melting can occur. Due to strong local surface overheating, fine cracks appear on the barrel's surface.

Due to wear inside the barrel and expansion it is possible for a quantity of gas to leak between the bullet and the barrel at a very high velocity forming swirls causing serious local wear.

Correct operation, maintenance and care of the barrel can prolong its life. This involves the following activities: cleaning the inside of the barrel before firing; inserting the bullet correctly into the barrel to avoid the shock produced when entering the grooves; observing the firing conditions so that the barrel does not heat up beyond the permitted limits; cleaning and greasing the barrel after firing to remove deposits and protect it when the gun is not used.

4. Conclusions

In summary, the life of the weapon depends on the life of the barrel, that is, on the number of shots fired, without important ballistic parameters (such as

muzzle velocity and firing accuracy) exceeding certain limits imposed by the purpose of the weapon. Thus, the technical resource of the infantry weapon depends on the resource of the barrel, the basic requirement being that the critical value of the barrel is not reached, above which the barrel cannot be overtaken and the weapon cannot be used for firing.

The main factor that ensures the increase of the barrel's life is its manufacturing technology, which includes: the right choice of material, its processing and treatment; the technological choice of the semi-finished product; the technological choice of the barrel's manufacturing (especially drilling and rifling) and the choice of the process to increase the barrel's interior wear resistance (Popescu, 2019).

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