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Evaluation of wear mechanism of special purpose machine elements

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Abstract. **The purpose of the paper is to evaluate the wear mechanism that occur in the artillery armament main part – gun tube. In order to achieve this purpose, the mechanism of wear has been derived by means of studying the information from literary sources and drawing conclusions. The topicality of the topic is dictated by the constant aspiration of scientists to derive a new theory, reduce the manufacturing resources and increase the wear resistance of the gun tube. The study of the problem led to an assessment of the processes occurring in the gun tube of the artillery system. As a result of the study, it can be pointed that a different theory of the wear mechanism of special purpose machine elements has been established.**

Keywords: Machine elements, tribology, wear.

I. INTRODUCTION

The classification - special-purpose machine elements of a gun tube of an artillery system is derived from that they are thick-walled tube with unique purpose. Their purpose is to give direction and certain values of progressive and rotating motion of the projectile.

Approximately 85% of their inner surface is cut in the shape of a groove that curve from left to right and up. These grooves are designed to coerce the projectile to rotate about its longitudinal axis. This, in turn, gives the projectile stability during its flight.

The rest of the inner surface is made smoothbore in the shape of the cartridge case of the ammunition intended for it. This part is located at the rear end of the tube.

Behind the rear end of the tube, it is located a special detail that closes it when a shot is fired.

To produce a shot, it is necessary to place the projectile and the cartridge case in the tube. This process is called loading. During the loading process projectile rotating band its cut into the grooves of the tube. The rotating band it represents a copper or copper-nickel ring made on the cylindrical part of the projectile. The purpose of the rotating band is to give the projectile revolutions of rotation around the longitudinal axis and to obturate the gunpowder gases during the shot.

As a result of the projectile loading and closing the rear end of the tube, a chamber is obtained. In this chamber, during the shots fire production, the gunpowder burns. As a result of this process, a force is formed that produces the initial forward and angular velocity of the projectile.

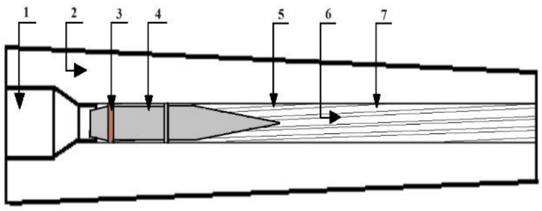

Fig. 1. Schematic diagram of an artillery gun barrel

1 – chamber; 2 – gun tube; 3 – rotating band; 4 – projectile; 5 – land; 6 – bore; 7 – groove.

The combustion of gunpowder, along with the projectile movement in the bore of the tube, causes wear on the gun tube. The wear, in turn, leads to decrease in the combat effectiveness of the artillery systems.

The problem exploration and finding ways to extend the wear resistance of gun tube it's an important scientific task. This task is derived from the striving to extend the resource of gun tube shots and increase the combat effectiveness of the artillery systems.

What has been written so far is based on general conclusions drawn from the study of the information from the sources [1], [3], [4], [10] and [20].

It is written in [6] that gun tube wear is a complex phenomenon and no single wear prediction theory is suitable for tube wear. It is shown in [6] and [7] that many scientists have established different theories, but there are still other scientists who try to approach in a different way to understand and increase the wear resistance of the gun tube, for example [7], [10], [15] and [17].

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This, together with the fact that theoretical research reduces the manufacturing resource, gives the topicality of the topic of the paper.

In addition, the purpose of the paper is to establish the mechanism of wear of the special purpose machine elements. To achieve this purpose, the wear mechanism is described based on summarized information from the described references at the end of the paper.

II. MATERIALS AND METHODS

The gun tube is made of alloy steel, with a coating applied to their inner surface. This coating aims to satisfy and increase the tactical and technical requirements of the gun tube. To these requirements refer: hardness, wear resistance, corrosion resistance, damage resistant, heat resistance, etc. [15].

However, as a result of the shot phenomenon, the gun tube is under the influence to severe intense thermodynamic and tribological wear. Wear character is not unique, it depends on the Caliber of the system and the number of shots fired per minute [6], [7].

Wear can be defined as loss of material, destruction of the metal net of the materials and change in the geometric characteristics of the elements. It is obtained as a result of the contact interaction between the elements during the movement of even just one of them. During sliding, rolling and even impact motion of one detail relative to another, the asperity of the interacting materials change the properties of the surfaces. This leads to the appearance of surface wear, which gradually increases to material loss.

Wear is influenced by the physio-chemical properties of the materials, as well as those of the contact environment. It is a complex process that is difficult to describe with the influence of single factor. For this reason, there are different types of wear that depend on the character of the contact surfaces and the properties of the surrounding environment of the contacting elements.

Based on this, it is necessary to clarify the processes occurring in the gun tube and to evaluate the mechanisms leading to its wear.

Researching the processes occurring in a gun tube, they can be divided into:

- loading the projectile in the bore of the gun tube;
- ignition of the gunpowder;
- formation of temperature and pressure from the burning gunpowder;
- formation a force causing the sliding motion of the projectile;
- rotating of projectile in the bore of the gun tube.

In the first process, impact wear occurs. This wear is characterized by two phenomena: erosion or percussion.

Erosion occurs as a result of the kinetic energy of solid particles present in the surrounding environment or liquid droplets of steam and their subsequent aggressive action on the material [2], [5]. Erosion wear occurs as a result of the flow generated by the high velocity of the burning gunpowder composition.

Erosion also occurs as a result of the fact that the process of loading the system takes place in environments with different concentrations of dust particles. As a result, there are various abrasive particles adhering to the rotating band. These abrasive particles contribute to increase the wear. In such cases, wear is called erosive-abrasive [18].

Percussion is developed by continuously repeating impact action on a metal detail. In the gun tube bore, percussion phenomena can be explained by the fact that during loading process the projectile is pushed into the bore with certain force. This process results in the projectile impacting the bore of the gun tube.

During the process of combustion gunpowder, temperature and pressure are form, which quickly increase to large values. This coerces the metal to expand. As the temperature and pressure drop, the metal returns to its original dimensions. Constant expansion and constriction lead to fatigue of the metal structure, which over time turns into a net of microcracks. Gradually, pieces of the metal break off from these microcracks.

The high temperature generated by the combustion of the gunpowder composition causes the metal to melt. This, in turn, contributes the wear mechanism to occur more intensive, as the molten metal deforms more easily.

In addition, the products of gunpowder combustion lead the chemical erosion of the metal [17]. A chemical reaction occurs during this process. This reaction can be explained by the interaction of the chemical products of the gunpowder composition with the surface layer of the metal. As a result of this reaction, the undesirable phenomena - corrosion and oxidation - are formed.

In cases where there is no motion of the elements, the chemical products of oxides can form a chemical film to protect the metal from corrosion. But the sliding motion of the detail wears away the chemical film and so the chemical reaction continues to develop. From this it can be concluded that chemical erosion requires both a chemical reaction and friction caused by motion of the workpiece [2].

Chemical wear gradually leads to the destruction of the surface layer of the material. Parts operating in a corrosive environment wear out faster than those that are not in such an environment.

But the gunpowder combustion also resulting to formation of pressure. This pressure forms the force that causes the projectile sliding motion. In the result, projectile acquires a forward velocity which gradually increases and reaches maximum value when the projectile exits the muzzle cut. As the projectile slides, it also begins to rotate.

In these motions occurs *adhesion wear, abrasive wear* and *fatigue wear*.

What has been written so far and what is yet to be written next is based on summary conclusions from a study of the information from the sources [2], [5], [8], [9], [12], [13], [14], [16], [17], [19] and [21].

During the movement of one body relative to another, the contact between them is formed at the tips of their asperity. The asperities are located on to the surface layers.

The characteristics of the surface layers are relevant to the interaction because they affect the actual area of contact, friction, and wear [2], [11]. The surface layers of the elements consist of micro and macro asperities (Fig. 2. – *line „2" and „3"*), which depends on the accuracy and method of manufacturing the machine elements.

In the movement of one element relative to another, the friction force is due to the contact of the asperity of the materials, where contact region is formed (Fig. 2. – *„b"*).

The contact region, in turn, forms the contact area (Fig. 2. – „b"), which consists of asperity of different heights (Fig. 2. – *line „1"*).

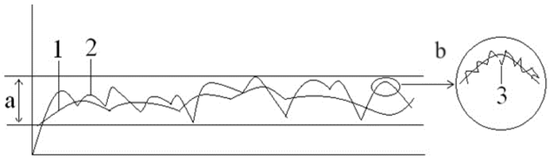

Fig. 2. An image of the asperity of the surface layers.

a – real contact surface; b – contact region;
1 – asperity; 2 – macro asperity; 3 – micro asperity.

The high stress on the tips of the asperity in the contact regions, when two elements are pressed against each other either under the action of the normal loading or under the action of combined normal or shear stresses, causes them to stick together, forming so-called contact bridges. As a result, in order to separate these contact bridges, a frictional force, called the adhesion frictional force, occur on the surfaces during relative sliding motion [2], [5].

The frictional adhesion force causes *adhesive wear*, which occurs as a result of the rupture of the contact bridges. This process concludes with tearing off a fragment from one surface and adhering it to the other surface. With continued sliding, this fragment can be attached to the original surface or completely removed. This process is influenced by the physical and chemical properties of the contacting elements and the environment in which they interact.

Abrasive wear occurs when elements in contact have a significant difference in hardness. In abrasive wear, the asperity of the harder material penetrates the surface of the softer material and fracture it. This fracture, with continued motion of the elements, develops into removal of material, in the form of thin chips or a whole fragment, from the surface of the softer element. In addition, this process is associated with damage to the surface through plastic deformation. In abrasive wear, the deformation of metals associated with it is considered in three ways: cutting, plowing and wedge formation [2].

Abrasive wear also occurs when there are solid particles between contacting elements. This makes abrasive wear similar to erosive wear. The difference between these two types of wear is that in erosive wear, the solid particles must have their own driving force.

In the bore of the gun tube under the action of the burning gunpowder, the subsequent sliding and rotating motion of the projectile, the solid particles that have caught move around the rotating band and the bore. They have their own driving force, but during loading of the projectile into the gun tube, these solid particles will fracture the bore on the inside of the gun tube.

As a result of the above, it can be assumed that abrasive and erosive wear are processes that bring the gun tube to wear.

The constantly repeated loading and firing processes lead to *fatigue wear*. Fatigue wear of the material usually occurs after repeated cycles of sliding, rolling and impact, even with negligible friction. These cycles are associated with loading and unloading of the wear detail. Under loading process, the performing action of the wearing detail is taken into account. For the gun tube, the loading and firing processes represent this action.

These cycles can lead to surface and subsurface cracks. Gradually, these cracks develop into the breakdown of material and pits formation.

The sliding and rotating motion of the projectile in the bore of the gun tube are assumed to be complex motions. As a result of these motions, frictional stresses arise, which cause shearing stresses in the contact region. In this way, a cyclic deformation is formed in the surface layer, which gradually develops into surface fatigue.

The sliding motion is usually higher, comparable to rolling motion observed in a process of wear. During the sliding motion, the adhesion and abrasion processes develop through the asperity of the surface layers of the contacting elements. In these processes it is possible the asperity to pass each other without adhering or abrading, but this causes them undergo to plastic deformation. In continuous cycles of this deformation cracks form and extend due to fatigue of the material, which gradually results to the loss of fragments of the metal.

Through new technologies, it is possible to simulate and study the described processes in a virtual environment.

New technologies provide an ability to construct virtual prototypes of an existing or future product to be studied through the specialized software products for engineering analysis. This would help to create new series of products with changed characteristics [11].

III. RESULTS AND DISCUSSION

As a result of the described processes, the wear mechanisms of special purpose machine elements, which is the gun tube of an artillery system, can be summarized.

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Figure 3 shows the approximate sequence of processes leading to wear of the gun tube of artillery systems. This can be a starting point for more in-depth research of the problem related to the wear of artillery tube.

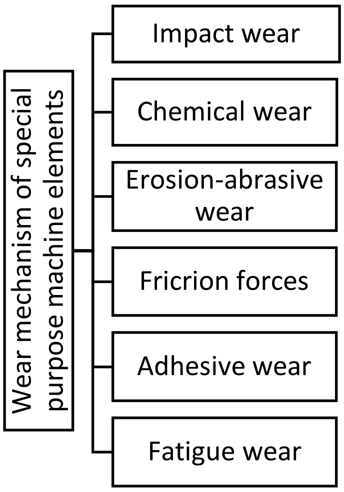

Fig. 3. Approximate consecution of wear mechanism of special purpose machine elements

The derivation of the mechanism of wear of artillery tube is based on a research of available literature sources relating to the wear of machine elements. Specialized literature related to the processes occurring in the artillery tube during its firing was also used.

To clarify the credibility of the derived mechanism, it is necessary to establish a methodology for studying the wear of the bore of the gun tube.

Establishing of such a methodology requires the consistent development of analytical models taking into account the frictional forces and the resulting amount of wear.

The represented wear mechanism can assist the process of deriving the analytical models of wear. The development of the models is necessary to perform theoretical researches and to have the opportunity to predict the number of shots before the final failure of the gun tube occurs.

IV. Conclusions

Through research and drawing conclusions on the basis of literary information on the studied problem, a wear mechanism of special purpose machine elements has been established.

This mechanism is necessary to develop a methodology for predicting the wear resistance of the gun tube. The ability to predict the gun tube wear resistance is an important part of scientific work for the education and advancement of the engineer involved in the design of artillery systems.

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