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INVESTIGATIONS OF BARREL BORE WEARING MECHANISM

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In this paper the investigation results of a barrel bore wearing are presented. Analysis of alterations occurring in the upper layer of the barrel is carried out and the causes as well as the mechanism of the barrel bore wearing are found out.

1. Introduction

Development tendencies in the field of classical armament are connected, among others, with construction and introduction to army equipment the quick-firing weapons with projectiles having large initial velocity. Thus, for production of constructional elements, especially barrels, the use of new materials and technologies ensuring theirs sufficient sustenance is demanded. Of course, when selecting the proper technology one should know the operation and co-operation conditions as well as reasons and factors resulting in the wearing. In the case of barrels there is a lack of comprehensive studies in this field and the literature data is incomplete. Data concerning the wearing mechanisms of barrel bores presented in accessible sources (see References) are incomplete. So they cannot be treated as the basis for detailed determination of the effects accompanying the firing, which affect the upper layer of barrel bore wearing. This work attempts to present comprehensively the wearing mechanism of barrels during firing.

2. Investigations of the upper layer state of barrel bore after firing

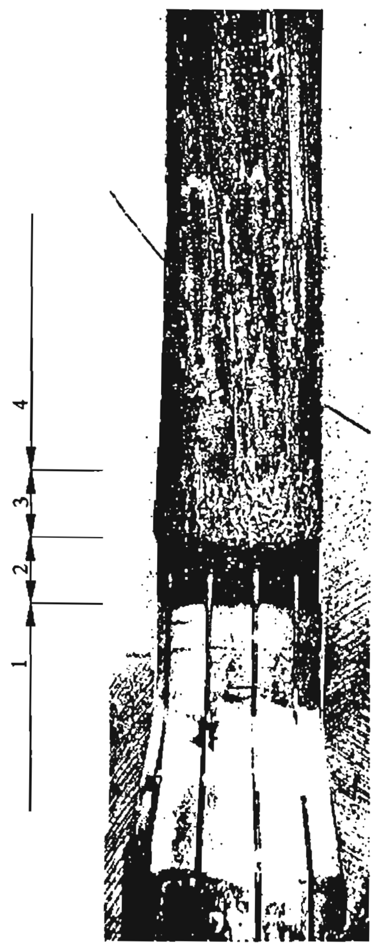

Fig. 1. Barrel bore with indicated wearing zones

The investigations were carried out in terms of analyzing the bore of 23 mm barrel after 3000 shots of firing tests. The barrels were made of 3OHN2MFA steel in accordance with the production technology. The barrel bore had the galvanic chromium layer with the mean thickness of 40 μm. For examinations the barrel was cut along its symmetry plane and its upper layer has been studied. The initial observation proved the existence of six characteristic zones of wearing along the barrel bore, four of which are shown in Fig.1.

The first zone occupies the cartridge chamber region. The bore surface in this zone is coated by the glossy chromium without the apparent altering of the surface shape.

The second zone occupies the region of resting position of the projectile rotating ring. It is characterized by the dark surface with no signs of damages.

About 6 mm wide, the third zone begins just after the front edge of the rotating ring. In this zone are apparently visible, with the unaided eye, dimensional changes of the bore as well as surface damages in the form of longitudinal furrows and the cracking net. The bore surface is pitted, one can notice the complete lack of the rifling contour in this zone. The chromium layer does not appear.

The fourth zone is about 60 mm long. There exist the apparent wearing effects in the form of rifling contour destruction. The field and furrow destruction decreases in the direction of barrel outlet. Moreover, on the uncovered bore surface the cracking net and large losses of chromium layer are visible. In the outlet direction of this zone the regions coated by copper layer are visible.

In the fifth zone there do not occur the mechanical effects of the surface damage.

In the sixth zone (around the barrel outlet) the bore surface is coated by the glossy chromium.

After the initial observation of damages the microscopic examination of non-etched microsections was carried out.

In the first zone there were found no material losses. The chromium layer adheres the base firmly. There were noticed only small numbers of crackings in chromium layer along the entire circumference.

In the second zone numerous crackings and splinters of chromium occur. Some of these crackings penetrate the material bulk. Particularly deep crackings occur in the Raveli's grooves (Fig.2).

In the third zone the chromium layer is missed and numerous material crackings occur, visible in the longitudinal (Fig.3), as well as, lateral cross-sections (Fig.4). Crackings in the region of largest damage of the barrel bore appear to be normal to the inner surface of it, however, in the regions closer to the barrel outlet they appear to be inclined towards the projectile motion.

In the fourth zone the numerous crackings of the chromium layer and uncoated base occur. In most cases under the crackings through the chromium layer, the surface crackings of the barrel material occur. It is possible to find the numerous splinters of the chromium layer (Fig.5 and Fig.6). Considering the surface, they are smaller in grooves and larger in the rifling contour fields. Some fragments of the field contours are completely free from the chromium

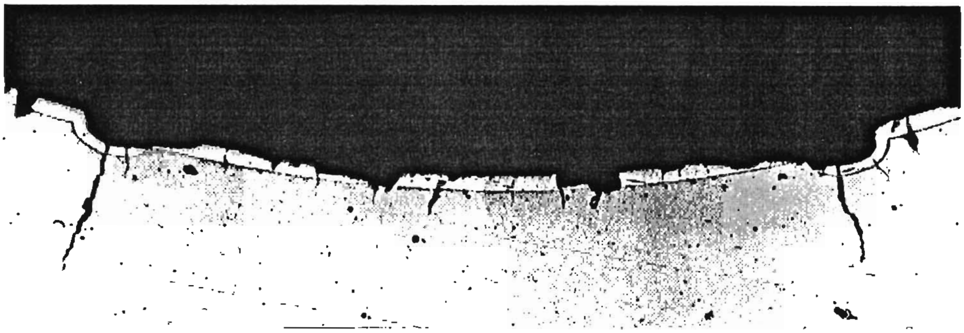

Fig. 2. Barrel cross-section in the second zone (magn. 20×)

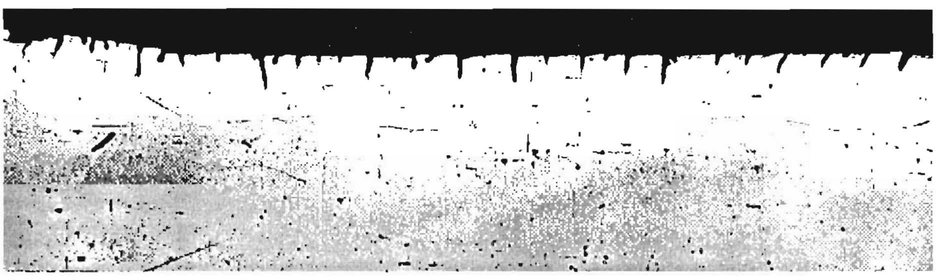

Fig. 3. Barrel coaxial section in the third zone (magn. 20×)

Fig. 4. Barrel cross-section in the third zone (magn. 20×)

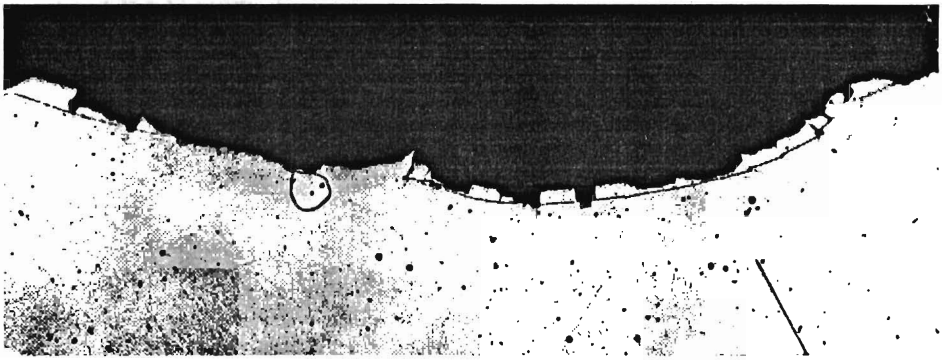

Fig. 5. Barrel cross-section in the fourth zone (magn. 20×)

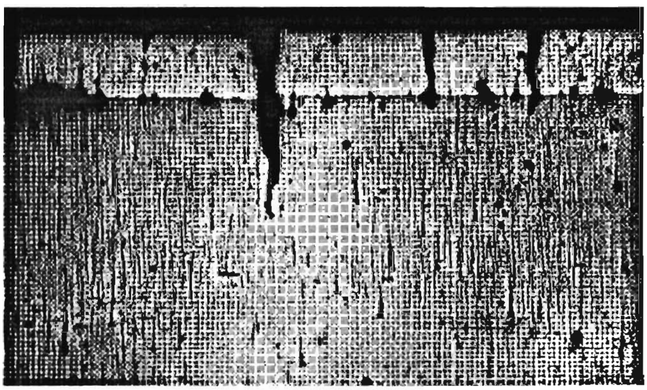

Fig. 6. Barrel cross-section in the fourth zone (magn. 100×)

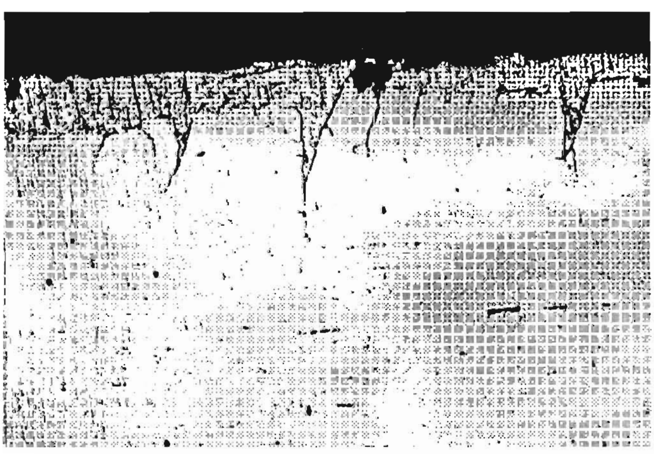

Fig. 7. Barrel coaxial section in the fourth zone – visible is a copper layer on the surface (magn. 100×)

Fig. 8. Barrel cross-section in the fourth zone – visible is copper filling the crackings (magn. 500× etch. Mi15Cu)

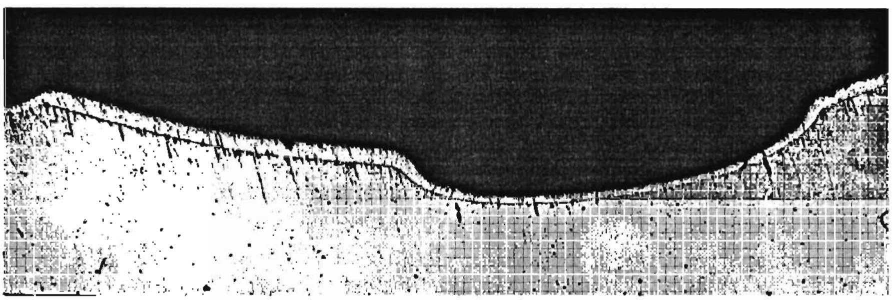

Fig. 9. Barrel cross-section in the fifth zone (magn. 20×)

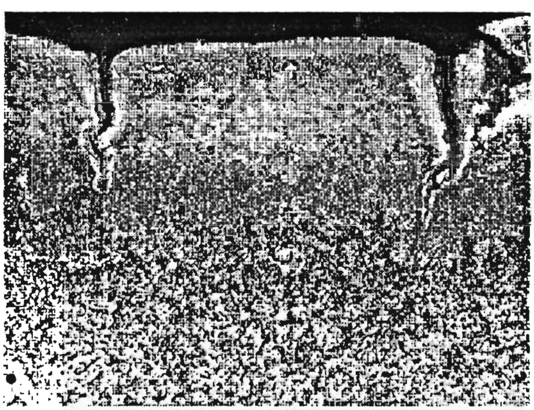

Fig. 10. A metallographical structure occurring in the third zone (magn. 500× etch. Nital)

layer. Moreover, in the regions of spalled chromium the copper layer occurs, which also fills the local crackings of the base (Fig.7). The way of crack filling by copper as well as the chromium splinters appearance show that copper penetrates the slots while being in the liquid state. It is also supported by the copper structure presented in Fig.8.

In the fifth zone the chromium layer was not destroyed except the small number of crackings (Fig.9).

Then the examinations of structure and measurements of microhardness have been carried out, mainly in the region of largest damage, that is in the third and fourth zones, respectively.

In the third zone, at the surface, there were identified four different structures (Fig.9). At the surface, up to the depth of 0.01 mm a white etch resistant structure with inclusions of the form of carbides occurs. Low hardness (245 μHV) in this region suggests that it is the ferrite structure. The 0.04 mm thick next layer is etch resistant and has hardness of 1080 μHV. It indicates that in this region the martensitic structure occurs. The successive darker layer has the sorbitic structure with hardness of $458 \div 301$ μHV. Microhardness distribution in the layer is shown in Fig.11.

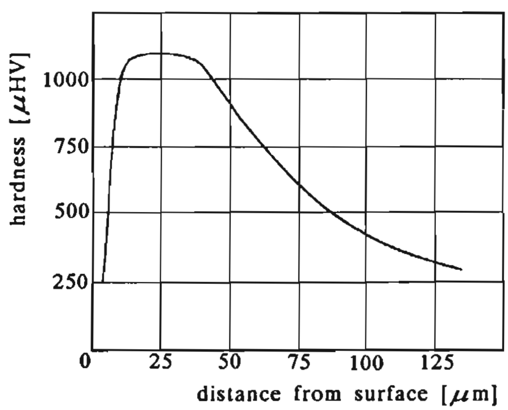

Fig. 11. Hardness distribution in the surface layer of the third zone

In the fourth zone there were found no essential structural differences between the surface layer of the barrel and the base in the regions of the chromium presence (Fig.12). In the regions of chromium splintering the surface martensitic layer is visible (Fig.13), which is very much a like the third zone.

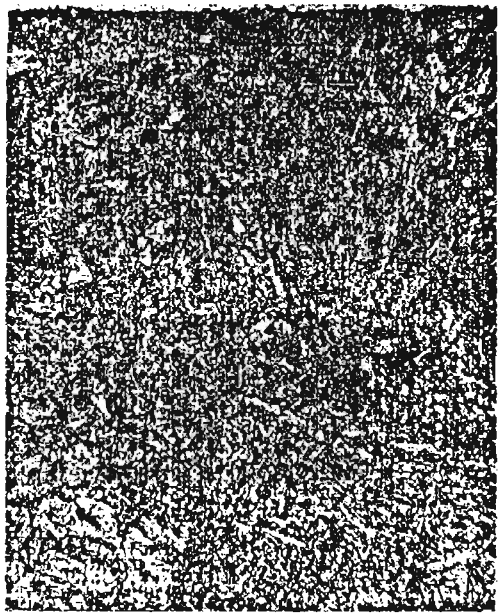

Fig. 12. Metallographical structure in the fourth zone (magn. 500× etch Nital)

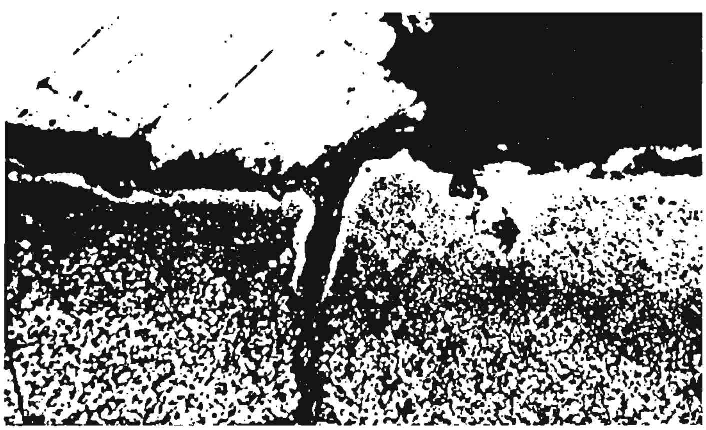

Fig. 13. Metallographic structure occurring in the fourth zone – visible is the bright non-etchetable zone at the surface (magn. 500× etch. Nital)

3. Analysis of obtained results

On the basis of the presented analysis of damages one can find that the major wearing of the inner layer of barrel bore takes place in the third and fourth zones, respectively.

Here occur: shape alterations, loss and damage of the base material and chromium layer, as well as, structural changes in the surface layer of the barrel bore. The wearing forms being found are due to the heat and gas-dynamic interaction of the burning products onto the barrel wall. The martensitic structure appearing in the surface layer proves this thesis, since it was no such a structure before the firing. This means that during the firing the surface layer of the barrel is heated above the austenitic transformation temperature and then it is cooled with the speed greater than the critical one. As a result the "overheated" layer of a relatively small thickness appears. This creates the conditions for rapid flow of heat into the "cold" part of the wall after a fire and enables creation of martensite. This effect repeats in cycles at the firing frequency. The "austenite-martensite" transition is connected with alteration in the crystallographic lattice parameter affecting the surface layer considerably producing internal stresses referred to as the hardening stresses. Due to it the cracking net in the chromium layer appears, which creates the local sources for the barrel material cracking. The cyclic character of the process results in the increase in cracks number, and deepening and joining. Due to it the loss of the material in the surface layer appears.

The shape and contour of crackings in the third zone proves the additional effects accompanying the heating. Rounding the slot edges can be due to the partial melting and erosive drift by gas burning products flushing the wall. It can be assumed that the combustion gases move in the barrel with the projectile velocity. In the initial phase of the motion the projectile velocity is small, thus there appear no conditions for aerodynamical erosion of the wall surface. However, analysis of the "projectile-barrel" system dimensions shows that between the rotating ring and the barrel bore, in the region of transition cone, there exists the constructional clearance. Due to this the ring slot of a nozzle character occurs through which the powder gases can flow. Expanding in the slot they locally reach the considerable velocity intensifying the wall heating and raising the possibilities for erosion drift of the melted metal layer. At transition from the third to the fourth zone the erosic interaction of gases vanishes. It is connected with the tightening of projectile in the barrel bore due to deformation of the rotating ring and filling up the firing contour.

It should be excluded the possibility of surface damage in the third zone due to friction of the rotating ring in the barrel bore. The friction is not essential factor, due to the fact that cracks are directed normally to the surface. However, the apparent action of friction resulting in the cracks inclination appears in the fourth zone.

4. Conclusions

The presented results of studies and the analysis allow us to formulate the following conclusions given below.

- The main factors affecting the wearing are:
  - The thermal fatigue of surface layer due to cyclically appearing structural transformations (hardening and releasing)
  - Aerodynamical erosion processes of during the gas flow between the rotating ring and the inner surface of a barrel
  - The surface plastic deformation of the heated material layer during the motion of projectile.
- The wearing process of surface layer has different intensity and character along the barrel bore, the major wearing occurs in the third and fourth zones:
  - In the third zone showing the largest size, morfological and structural alterations dominates the wearing due to the heat fatigue and erosion drift of the surface
  - In the fourth zone dominates the wearing due to the heat fatigue and the surface size alterations as a result of plastic deformation of the surface layer.

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Badania mechanizmu zużywania się przewodu lufy

Streszczenie

Przedstawiono wyniki badań zużywania się przewodu lufy. Przeprowadzono analizę zmian zachodzących w warstwie wierzchniej lufy oraz określono przyczyny i mechanizm niszczenia przewodu lufy.

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