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Theoretical and practical aspects of the identification of the bladed weapon on the example of the SG 98/05 bayonet to the Mauser rifle based on metal science research

Abstract. *The article examines the studies of the bayonet fragment with severe damages of metal found in the city Kremenchuk (Ukraine) in one of the canals on the outskirts of the city, near the Dnipro River. Theoretical research to study blade weapons of the World War I period and the typology of the bayonets of that period, which made it possible to put forward an assumption about the possible identification of the object as a modified bayonet to the Mauser rifle has been carried out. Metal science expert examination was based on X-ray fluorescence spectrometry to determine the concentration of elements in the sample from the cleaned part of the blade. Analysis of the chemical composition showed that the blade was made of hardened carbon steel alloyed with silicon, chromium, manganese, nickel and copper. Measure results of the chemical composition of the object correspond to steel for castings of grade 55L with an average blade hardness of 42 HRC. Manufacturing technology of the casting corresponds to the end of the XIX – the beginning of the XX century with the use of converter production. The bayonet blade was subjected to strengthening heat treatment in the form of hardening and medium tempering. Metallographic analysis showed that the research object of blade fragment suffered*

corrosion cracking between crystals or along the body of grains, indicating a long stay in silty deposits. The identification of the research object has been carried out using applied technologies based on visual inspection with a description of the state of conservation and comparison with the results reflected in scientific periodicals; metal science expertise; determination of weight and size characteristics and their compliance with the original, including experimental reconstruction, which identifies the preserved fragment with the original drawing at the control points. A comparison of the chemical composition of the blade steel and the "Haenel" steel, differing in concentration and additional alloying elements has been made. The remains of the royal monogram imprint of the stamp and the absence of the regimental stamp have become the basis for searching through catalogs of registered bayonets. This allowed the identification of the object under study as part of the German imperial modified bayonet model 1898/1905 for the Mauser rifle, which was manufactured in the period from 1915 to 1918. Prospects for further research are seen in an increase in the number of metal science examinations for more accurate identification of discovered specimens.
Keywords: *expert examination; age determination; archaeometallurgy; experimental reconstruction; stamp; "Butcher"*

Introduction.

The current state and prospects for the study of blade weapons of the World War I period have not been sufficiently reflected in scientific periodicals. While highlighting this issue, attention should be paid to the publication (Bennett, 2019a), which describes the two main types of bayonets that were used in the Imperial German Army. The author focuses on setting out the origins of this type of weapon and explaining their current use, that is, the article is more overview in nature. The basic research on this topic is the work of Anthony Carter (Carter, 1984), summarizing the known information about the SG 98/05 bayonet and its prototype SG 98/02, which have much in common in the design of the main elements. The works (Lübbe, 2000; Rüdiger, 1994/2000) contain close-ups of manufacturer's stamps, markings and individual parts, which can help in identifying each specific bayonet. Presented albums and catalogs are valuable reference books for collectors of bayonets at the same time metal science examination would enhance the subject of the article under consideration. Nowadays, scientific interest in the bayonet is very limited in the context of the rapid and sustainable development of weapons, which has been such a noticeable sign of war since the mid-19th century, and its impact on the nature of the battle is barely noticeable (Stone, 2016).

Publications (Ballard & Bennett, 2017; Ballard, 2018) are devoted to an overview of the weight characteristics of the British Army bayonets, which are based on a statistical analysis of data on the compliance with the required minimum and maximum weight range of the finished product. Such an approach does not allow the identification of specimens that are in a poor state of conservation or which integrity has been disintegrated. The article (Bennett, 2019b) shows the history and characteristics of the Ottoman bayonets of the American Peabody-Martini rifle. These three bayonets provide a classic illustration of the bayonets' typology of this period, without thoroughly examining the metal they were made of.

It should be noted on the metallographic analysis of two knives found in Kobilić (Republic of Croatia), presented under the authorship of (Thiele, Hošek, Antonić, & Rácz, 2017). However, there is no data on the chemical composition of these knives, which is important from the point of view of a precise study of products. The paper (Hošek, Bárta, & Šmerda, 2017) shows the application of metallographic analysis to the study of a sword from Kyjov (Czech Republic). Experimental reconstruction made it possible to obtain technological information in the production of this type of weapon, but questions arise on the compliance with the manufacturing time.

The prospects of researches in the field of archaeometallurgy using various methods of spectroscopic analysis are discussed in some scientific publications (Pearce, 2016). The author notes the importance of greater use of analytical data by archaeologists and, therefore, ultimately to better identification of samples. In particular, the article (Welton, 2016) overestimates the functional properties of 52 early Anglo-Saxon spearheads and 118 knives, also rethinking their technological properties based on the determination of the carbon and phosphorus content in wrought iron. Practical achievements, except local thematic studies, have not yet been spread in the scientific community (Charlton, 2015), that actualizes work in this direction. There is a need for a thorough study of objects using applied technologies.

The aim of the paper is to identify the object of research as part of a modified bayonet (cleaver bayonet, knife bayonet) of 1898/1905 (SG 98/05) to the 1898 Mauser rifle.

Achieving this goal necessitated the following tasks:

– historical investigation and identification of a probable bayonet fragment;

– determination of chemical composition; metallographic analysis and reproduction of the technological scheme of manufacture.

Research methods.

A fragment of blade weapon with significant damage was provided for the study (Fig. 1). The handle and part of the blade are preserved. There are wood particles, two metal screws, and the remains of a button on the handle. The sample was found in Kremenchuk (Ukraine) in one of the canals on the outskirts of the city, near the Dnipro River.

X-ray fluorescence spectrometry (RFS, XRF) GOST 28033–89, which is used to determine the concentrations of elements in the range from 0.001% to 100% in various substances has been used.

Quantitative X-ray fluorescence analysis has high accuracy and reproducibility of results, provided that the requirements for representativeness of the sample are met. High accuracy with low analysis costs is guaranteed by the stability of modern instruments, which eliminates the need for repeated measurements or frequent recalibrations. The quantitative analysis is based on the dependence of the intensity (I) of characteristic X-ray radiation on waves of various wavelengths. The nature of the dependence is experimentally established by calibration, that is, by measuring the intensity of characteristic fluorescence in several reference (standard) samples with a precisely known concentration (C) of the element that is being determined. The recalculation of the measured intensities of the elements of the investigated object in the unit of concentration is based on the performed calibration and is described mathematically using the calibration function in the form $I = aC + b$. The result of quantitative analysis is the exact value of the concentration of the element in the test object, which is expressed in %, ppm (g/t), g/kg and mg/l.

Figure 1. General view of the research object (photo taken by the authors in 2021).

The qualitative analysis is based on the presence or absence of lines of characteristic radiation of the element in the sample spectrum. An element is considered available in the investigated object if less than two lines of characteristic radiation are detected in the spectrum. The identification of these lines of elements is carried out by setting the wavelengths of the spectrum peaks and searching for the found values in the database of X-ray lines. This operation is carried out by computer means. The analysis result is presented as a list of available elements in the sample and the elements presented in the sample in very small quantities (traces).

The identification of a substance is carried out to establish the correspondence between the composition and certain physical properties of the investigated and reference samples. This type of analysis is important when looking for any difference in the composition of the two samples. X-ray fluorescence spectrometry allows a detailed comparison of samples by the characteristic spectra of the elements, as well as by the intensity of the background (bremsstrahlung) radiation and by the shape of the Compton scattering bands. This is important if the chemical composition of two samples is identical according to the results of quantitative analysis, but the samples differ in other properties, in particular, grain size, crystallite size, surface roughness, porosity, moisture, the presence of crystallization water, polishing quality, spray thickness, etc. Identification is performed on the basis of careful comparison of spectra, without the need to know the chemical composition of the sample. Any difference in the compared spectra certainly indicates a difference between the research object and the standard. The result of such research is an accurate confirmation or disproof of the identity of the two samples.

For carrying out experimental researches, serial and special laboratory equipment such as a forensic line for photography and a built-in digital camera; angle grinder with modified stable for it; stationary Rockwell hardness tester NOVOTEST TC–P; electronic Vernier caliper Miol Premium 150 mm (15–241) Digital Microscope USB 500X Black as well as X-ray fluorescent spectral analyzer ElvaX Plus were used. The ElvaX Plus device is designed for rapid, quantitative and qualitative analysis of the composition of metal alloys, powders, liquids, bioassays for the content of chemical elements from sodium (Z=11) to uranium (Z=92) in a wide range of concentrations.

Portable X-ray fluorescence analyzer ElvaX Plus is a new generation of analytical equipment for high-precision analysis of the elemental composition of various substances. ElvaX Plus is a benchtop energy dispersive X-ray fluorescence spectrometer that does not require liquid nitrogen for operation and storage. The spectrometer allows carrying out a quick-look non-destructive elemental analysis of a substance at all stages of the production cycle or laboratory research without preliminary sample preparation. The device is contained in the State Register of Measuring Instruments approved for use in Ukraine under the number U1411–01. The device is contained in the State Register of Measuring Instruments approved for use in Ukraine under the number U1411–01. Certificate of Conformity to the Approved Type of Equipment and Measuring Instruments is No. UA–MI/1–971–2001. The results obtained by X-ray fluorescence spectrometry (XRF, RFA) fully meet the requirements for the accuracy of the analysis according to category III (OST 41–08–205–99).

Historical investigation and analytical comparison of the typology of a probable bayonet part.

Since September 16, 1915, by order of the Military Department of the German Empire, the 1898/1905 model bayonet has been modified by introducing a combat bayonet with double edged blade, first in foot troops and jaeger troops, and then in the entire army (Fig. 2).

Since 1915, the bayonet has been produced with a small recess for the gun barrel at the top of the guard and a protective plate on the handle (Bennett, 2019a). Since 1916, the mass production of the model began. This model was the most widely used German bayonet during the World War I. The people called the bayonet “Butcher”, which means “butcher”, since the blade of this bayonet resembled a butcher’s knife in its shape.

During World War I, bayonets of this model were supplied to Turkey along with 1898 Mauser rifles (Bennett, 2019b). After World War I, the 1898/1905 model bayonet continued to be used in the Reichswehr and the police, remaining in service with individual units until World War II, despite the fact that already from 1923 it was ordered to replace all bayonets of this model in the army with model bayonets 1884/1898 (new type). In addition to Germany, bayonets of this model were also used in Yugoslavia, Turkey, Belgium, Poland, Czechoslovakia, and other countries.

Figure 2. Photo of soldiers with bayonets, model of the year 1898/1905 (Flickr, 2011).

The materials of Anthony Carter (Carter, 1984) were used to highlighting and fixing the elements necessary for the identification of the discovered specimens and their general condition.

At the beginning of the World War I, one significant defect was discovered in the bayonets. While mounting these bayonets on a carbine 98 (Kar 98) and shot, the flame, and gas pressure led to the handle cheeks damage in the form of charring and chipping off pieces of wood. Therefore, it was decided to protect the handle of the bayonets from the flame of shots with a steel plate. Wooden pads were ground off 0.6 mm over the entire inner surface and from the side of the handle spine. The gun barrel half-ring ("ears") was ground off on the crosspiece, the holes for cleaning the ramrod channel in the linings, and the protective plate was aligned (Fig. 3).

Figure 3. SG 98/05 bayonet of old (a.A. – alter Art) and new (n.A. – neuer Art) type (Gotavapen, n. d.).

One can also distinguish transitional and noncombat (ceremonial) bayonets. Transitional SG 98/05 n.A. have a modified crosspiece, but they are not equipped with protective plates. Transitional SG 98/05 a.A. have fire protection plates, but the crosspiece has remained unchanged. The noncombat bayonets of rather low quality are nickel-plated copies of the service ones, in which the blade and the handle are one whole, which gave the finished product considerable strength, since in the ceremonial ones they were fastened separately with a single rivet.

The use of bayonets with a saw on the spine by German troops led to widespread condemnation of Germany by its opponents and the fear of German soldiers to be caught with such a bayonet, which inevitably meant extrajudicial reprisals. In the novel "All Quiet on the Western Front" by E. M. Remark such an episode was described. The final order to remove the saws was issued in early 1918 (Bennett, 2019b). The removal process was organized in repair shops at military units, as well as at arsenals. Comparison of bayonets with a saw, with a ground-off saw and without a saw is shown in Figure 4.

The blade of the bayonet is single-edged, with fuller on both sides and an extension in the lower third. The combat tip contains a sharpening not only from the side of the cutting edge but also to a length of 4 cm from the blade edge on the reverse side. All bayonets were made from a sharpened false blade. The handle is formed by two wooden cheeks, fastened to the shank with two screws. The hole for cleaning the groove in the handle is rectangular, located in the grip cheeks, next to the crosspiece. The head of the handle has a T-shaped groove with a cylindrical expansion and a spring latch with an internal spiral spring. The crosspiece is with the end bent back. Iron sheaths are with a hook and a ball at the end.

Visual inspection revealed that the discovered specimens are a new type of bayonet without a saw. This is evidenced by the presence of remnants of the protective plate and the shape of the gun barrel half-ring. The remainder of the 73 mm blade rejects the possible options for bayonets with a saw and with a ground-off saw since there is no bevel of the spine of the blade, which began at a distance of 25 mm from the crosspiece.

Figure 4. SG 98/05 bayonet with a saw (m.S. – mit Säge) with a ground-off saw (abg. – sägeabgeschliffen, which means "saw removed") and without a saw (o.S. – ohne Säge) (Gotavapen, n. d.).

A drawing of a fragment of a bayonet is shown in Figure 5. The main dimensions by which the object under study can be identified are indicated. Control points are determined in the form of two metal screws and the remainder of a button. The blade thickness at the heel is 6.6 mm, the thickness of the handle cannot be accurately determined due to significant damage to the wooden cheeks and the protective plate. The weight is 315 g.

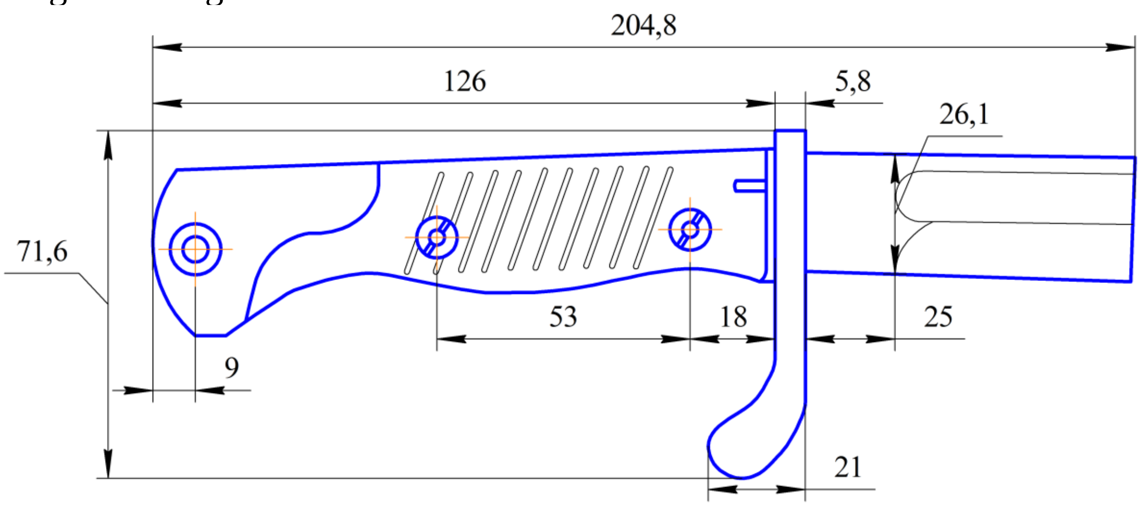
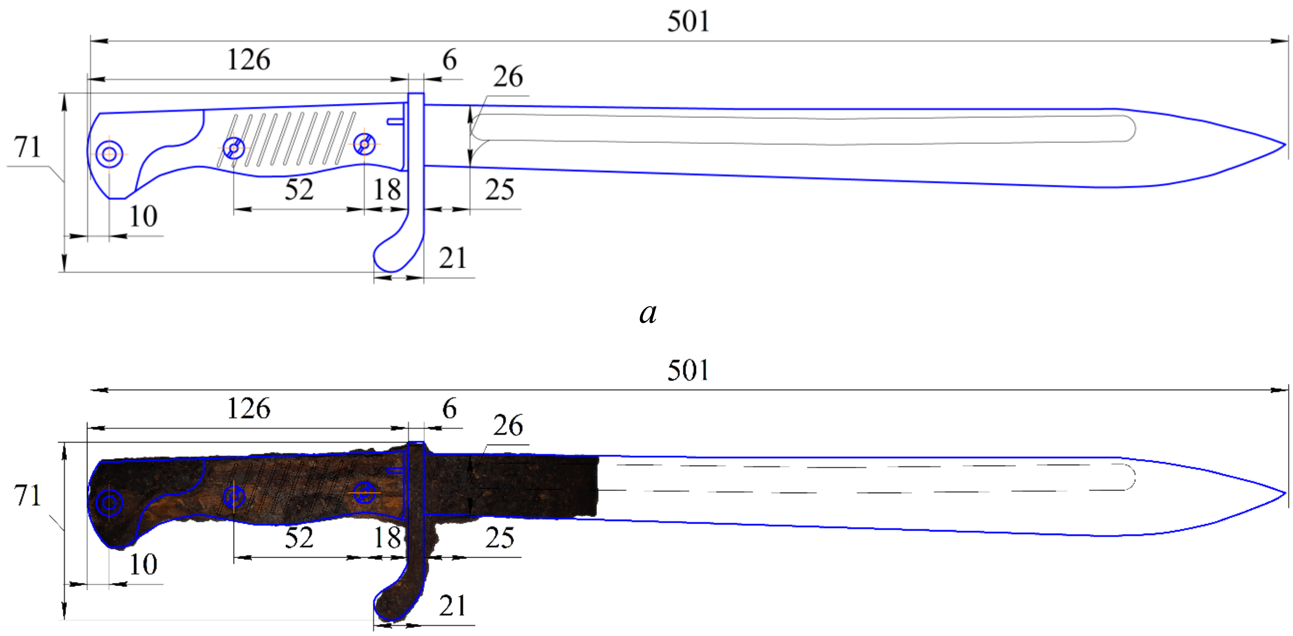


Figure 5. Drawing of the research object.

Experimental bayonet reconstruction based on the identification of the preserved fragment with the original drawing (Fig. 6).



a

b

Figure 6. Identification of the research object: *(a)* – original drawing; *(b)* – alignment on a photo scale of the discovered specimens with the original drawings and their coincidence in size and at control points.

It is worth noting the coincidence of the dimensions of the surviving handle, its shape, and the position on it of two metal screws and the remainder of the button, together with a part of the blade, corresponds to the original drawing of the bayonet and confirms the identification of the research object.

Metal science expert examination.

To study the object received for examination, samples were taken from the cleared out part of the blade. The results of the chemical composition measurements of the sample by the XPS (X-ray photoelectron spectroscopy) method are presented in Table 1.

Analysis of the chemical composition showed that the bayonet blade was made of hardened carbon steel alloyed with silicon, chromium, manganese, nickel and copper. Excessive phosphorus content results from strange contamination. A more detailed method using the results of metallographic studies and hardness measurements to estimate the phosphorus content in iron artifacts is presented in (Thiele & Hošek, 2015). Despite certain limitations, the method proposed by the authors can be used to estimate the phosphorus content in archaeological iron studied at the present time or in the past. The article (Thiele, Hošek, Kucypera, & Dévényi, 2015) discusses the phosphorus content in phosphorus iron, which was used as a special material for welding samples.

Table 1. Results of measuring chemical composition.

Atomic number	Element			Series	Intensity	Concentration, %	55L GOST 977
13	Al	Aluminium	Aluminum	K	2575	0.4227±0.0247	–
14	Si	Silicium	Silicon	K	7123	0.4808±0.0154	0.20–0.52
15	P	Phosphorus	Phosphorus	K	2418	0.0804±0.0073	up to 0.040
16	S	Sulfur	Sulfur	K	3741	0.0442±0.0032	up to 0.045
22	Ti	Titanium	Titanium	K	0	<0.0070	–
23	V	Vanadium	Vanadium	K	963	0.0310±0.0156	–
24	Cr	Chromium	Chrome	K	23477	0.4808±0.0158	up to 0.30
25	Mn	Manganum	Manganese	K	19473	0.6186±0.0161	0.40–0.90
26	Fe	Ferrum	Ferrum	K	3805691	97.3462±0.0279	–
27	Co	Cobaltum	Cobalt	K	0	<0.0486	–
28	Ni	Niccolum	Nickel	K	3223	0.2211±0.0123	up to 0.30
29	Cu	Cuprum	Cuprum	K	4919	0.2384±0.0089	up to 0.30
33	As	Arsenicum	Arsenic	K	1296	0.0236±0.0026	–
41	Nb	Niobium	Niobium	K	0	<0.0027	–
42	Mo	Molybdaenum	Molybdenous	K	319	0.0035±0.0029	–
45	Rh	Rhodium	Rhodium	K	11587	<0.0001	–
74	W	Wolframium	Tungsten	K	130	0.0086±0.0086	–

The chemical composition of the object approximately corresponds to steel for castings grade 55L with an average blade hardness of 42 HRC. The hardness measured at the heel of the blade averaged 17 HRC. Such a difference in hardness may indicate that during quenching the blade was not completely immersed in the quenching medium and structural transformations took place only in the blade part and in the blade tip. The hardness is measured by the Rockwell method – by pressing a diamond cone into the sample under a load of 150 kg. The German analogue of steel 55L according to DIN (Iron and steel: Quality standards 1, 2018) is 1.0554 with the following mechanical properties:

– yield point: 205–412 MPa;
– tensile strength: 450–687 MPa;
– percentage elongation: 12–22%.

The structure contains non-metallic impurity sulfur inclusions. Sulfur is a detrimental impurity that gets into steel from cast iron. When interacting with iron, it forms a chemical compound – ferrous sulphide FeS, which, in turn, forms with iron – a low-melting eutectic with a melting point of 988°C.

In the process of repeated heating for rolling, forging, and heat treatment, the surface of the bayonet is subject to decarburization. Decarburized layer is a ferrite layer in the surface parts of parts, formed by the interaction (burnout) of the metal of the parts from the oxidizer, gases (H_2, H_2O, CO_2, O_2, air) at elevated temperatures. The decarburized layer is formed during heat treatment in air and leads to a decrease in hardness, fatigue ratio and hardening limits, and to the formation of hardening cracks. The depth of the decarburized layer is determined mainly by microstructural analysis methods and microhardness. After the final mechanical metal-working, the decarburized layer is removed and can be identified only in a few places on the bayonet.

The steel production technology of the object corresponds to the period of the late 19th – early 20th centuries with the use of converter production. The simplified technological scheme is: rolling → stamping → machining → heat treatment → final mechanical metal-working.

From the point of view of metal science, it is possible to draw unambiguous conclusions only about such production stages as rolling and heat treatment. Such production stages as stamping and mechanical metal-working are provided on the basis of existing equipment at the time of production and the lowest costs for mass production.

During rolling, the rod passes through the rolls that are at a certain distance from each other. After rolling, the desired cross-sectional profile is obtained. After rolling metal becomes a fibrous structure and has a high flexural strength, which is important for blade weapons. Then a blank of the required length is cut, which enters the stamp.

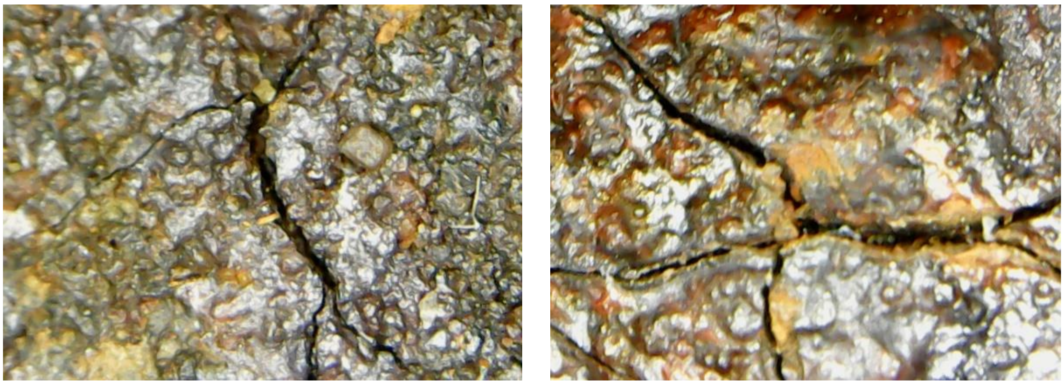
During stamping, a blank of the desired length and cross-section is placed in a stamping mold, which is attached to the hammer frame. Then the hammer with the second half of the stamp hits the blank heated to 1000–1200°C the required number of times to create the shape of a bayonet blade. At this stage, fullers and descents are formed.

Probably, after stamping, the blank still did not have the necessary geometric parameters and required refinement on grinding machines. The need for mechanical processing before heat treatment arises due to the fact that after hardening the steel becomes harder and less amenable to turning and grinding. Thus, in order to reduce costs in the production of any part, manufacturers try to give the most accurate shape of the blank before heat treatment, so that the allowances removed by the final mechanical metal-working are minimal.

The heat treatment process consists of heating by quenching temperature, pouring into a quenching medium tank, cooling in the quenching, and tempering. After quenching, the blades were placed back in the furnace and medium tempered.

During heat treatment, a scale (iron oxide) and a decarburized layer are formed on the surface of the blade. Final mechanical metal-working removes the scale and partially decarburized layer of steel from the surface of the blade, giving it its final shape. Then the bayonet is collected and sharpened.

Metallographic analysis of the blade showed that the research object suffered corrosion of metals in soils and, partially, liquid corrosion when fully immersed. According to the mechanism, the process is electrochemical corrosion, in which the ionization of metal atoms and the reduction of the oxidizing component of the corrosive medium occurs in more than one act and their rates depend on the electrode potential of the metal. By the nature of corrosion destruction, it is continuous or general uniform corrosion, which occurs at the same rate over the entire surface of the metal. Stress corrosion cracking which is characterized by a relatively uniform distribution of multiple cracks over large areas of the surface has been observed. At each stage of the development of this type of corrosion, cracks arise almost simultaneously from many sources, the connection of which with internal or working stresses is not necessary. Under an optical microscope, it can be seen that cracks propagate between crystals or along the body of grains (Fig. 7).



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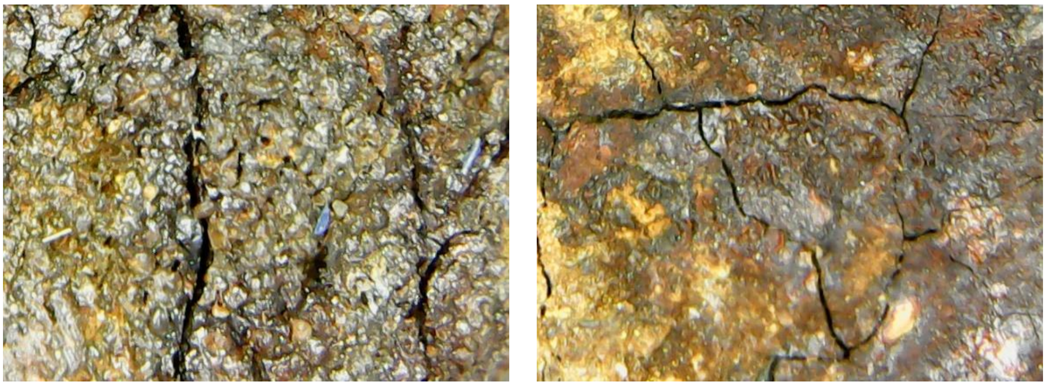


b

Figure 7. Metallographic analysis of the object: *(a)* – on the left; *(b)* – on the right.

As a result, there is irreversible corrosion destruction, which makes it difficult to study the microstructure of the metal in order to identify the phase structure.

Hardness 42 HRC and tempered troostite are typical of medium carbon steel after quenching and medium tempering. Tempered troostite has the form of a needle-like finely dispersed mixture of cementite and ferrite. The result of hardening at 850°C is quenched martensite and a small amount of residual austenite. Such a structure has maximum hardness and strength, but relatively low toughness. As a result of such heat treatment conditions the properties of the blade steel will certainly not correspond to the properties of the blade steel under study. After medium tempering at 350–400°C quenched martensite and retained austenite are transformed into tempering troostite. Steel with such a structure has increased toughness and reduced hardness compared to hardened martensite, but sufficient for bladed weapons.

The hardness of the blade steel at the heel was 17 HRC on average, and the structural components are ferrite and pearlite. This indicates that this part of the blade was not hardened and during the cooling process it was not immersed in a hardening medium. Inhomogeneity in the hardness of steel and a large number of metal inclusions indicate the low quality (by modern standards) of steel. On the other hand, the reduced hardness of the middle part of the blade could be the result of an increased tempering temperature precisely in this part of the blade to increase the toughness of the middle part of the blade.

Results and discussions.

As a comparison of the chemical composition of the blade the data of the company "Haenel", which produced such bayonets (Rüdiger, 1994/2000) are shown in Table 2.

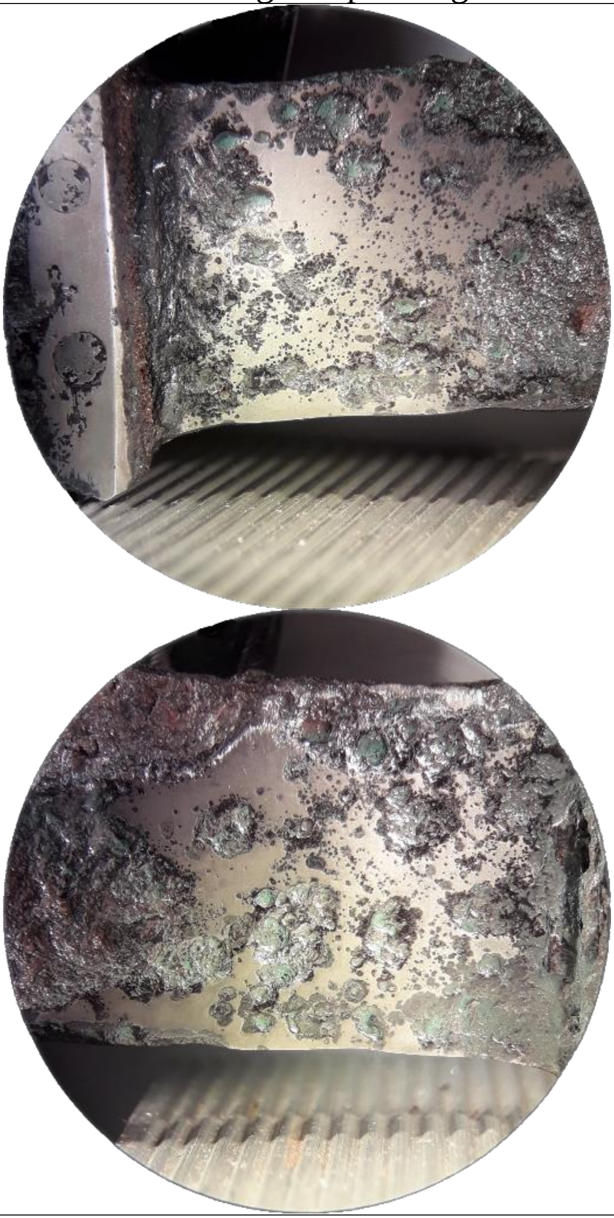
Table 2. Comparison of the chemical composition of the steel of the research object and the control sample steel.

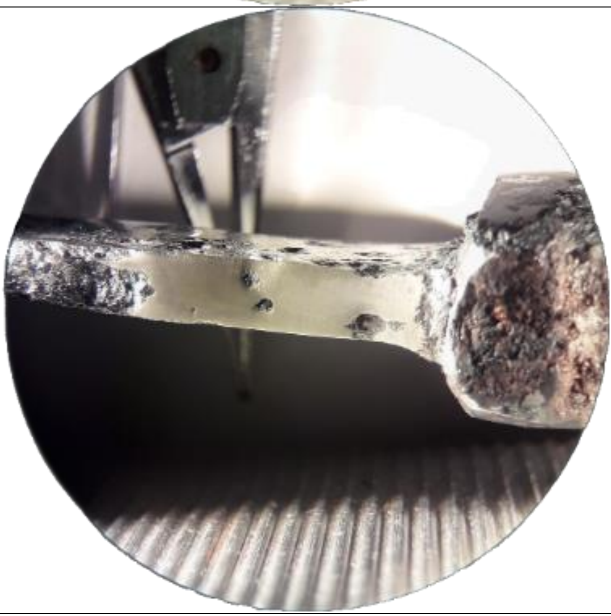
Element	Concentration	
	The research object	Control sample
C	0.52–0.6	0.70–0.9
Mn	0.6186±0.0161	0.55
Si	0.4808±0.0154	0.4
Cr	0.4808±0.0158	–
Cu	0.2384±0.0089	0.12
Ni	0.2211±0.0123	–
S	0.0442±0.0032	0.03
P	0.0804±0.0073	0.03

Analyzing the data in the table, it is worth noting the difference in the steel chemical composition of the research object and the steel having been used in the blades of the "Haenel" bayonets.

An important means for more accurate identification of bayonets is their stamping, which at the same time becomes the initial place for the corrosion propagation. Despite the poor state of the object the marks in the places of their possible location (on the blade heel – the stamp of the manufacturer; on the crosspiece – the regimental stamp, on the spine of the blade – a stamp with the ruler monogram and the year of being entered the bayonet into military service) have not survived (Table 3).

Table 3. Research results of stamping places.

Stamping place	Photo after cleaning and pickling the surface
Blade heel (manufacturer's stamp)	

Crosspiece (the regimental stamp)	 
The spine of the blade (a stamp of the royal monogram / the year of being entered the bayonet into military service	

Based on the research results, it can be concluded that there are remnants of the stamping imprints on the spine of the blade and that there is no regimental stamp on the crosspiece at all, since the depth of corrosion penetration in this place is small.

There are 40 known bayonet manufacturers, 4 royal monograms (Prussia, Württemberg, Bavaria, Saxony), years of the issue (1904–1918), which made it possible to catalog bayonets (Carter, 1984). According to the research results and search in catalogs, old-style bayonets were excluded; transitional; noncombatant (ceremonial) with saws, and with ground-off saws. Correspondingly, registered bayonets that have the stamps of the manufacturer and the royal monogram, but which do not have the regimental stamp have been sorted (Table 4).

Table 4. Catalog of registered bayonets.

Bayonet	**Type**	**The royal monogram / year of issue**	**Manufacturer**
SG 98/05	n.A.	W/15	Erfurt
SG 98/05	n.A.	W/15	Alex. Coppel
SG 98/05	n.A.	W/15	L.O.Dietrich * Gebr.Hartkopf
SG 98/05	n.A.	W/15	Ferd.Esser * Rich.A.Herder
SG 98/05	n.A.	W/15	Ferd.Esser
SG 98/05	n.A.	W/15	F.W.Holler
SG 98/05	n.A.	W/15	P.D. Luneschloss
SG 98/05	n.A.	W/15	Weyersberg & Co
SG 98/05	n.A.	W/16	Gottlieb Hammesfahr
SG 98/05	n.A.	W/16	Demag
SG 98/05	n.A.	W/16	F.W.Holler
SG 98/05	n.A.	W/17	Gottlieb Hammesfahr
SG 98/05	n.A.	W/17	W.K. & C
SG 98/05	n.A.	W/17	E.&F.Horster
SG 98/05	n.A.	W/17	Demag
SG 98/05	n.A.	W/17	F.Koeller & Co
SG 98/05	n.A.	W/17	Pack Ohliger & Co
SG 98/05	n.A.	W/17	Walter & Co * Gebr.Hartkopf
SG 98/05	n.A.	W/17	Walter & Co
SG 98/05	n.A.	W/17	Walter & Co * Carl Galle
SG 98/05	n.A.	W/18	H.Mundlos & Co * Rich.A.Herder
SG 98/05	n.A	W/18	F.W.Holler
SG 98/05	n.A.	W/18	Alex. Coppel
SG 98/05	n.A.	W/18	Walter & Co

* – blanks manufacturer and finishing treatment manufacturer

As a result, this made it possible to identify 24 possible coincidences for the selected features. All bayonets were manufactured between 1915 and 1918 exclusively in Prussia by specified manufacturers.

Conclusions.

As a result of the carried out complex research, it became possible to identify the bayonet SG 98/05 n.A. (year of production – 1915–1918) for the Mauser 98 (Kar 98) rifle, known as "Butcher". A completed historical investigation, visual inspection, and also determined the weight and size characteristics that made it possible to establish the key criteria by which the identification of the research object have been carried out. The performed X-ray fluorescence spectrometry made it possible to determine the chemical composition of the metal, which makes it possible to recreate the production technology of that time and to establish the steel grade for comparison with the data of the company "Haenel". Metallographic analysis of the blade showed the propagation of corrosion cracks caused by prolonged exposure to an aggressive environment, which led to a poor state of conservation, and, as a result, a lack of a clear stamp imprint. Catalog searching of registered bayonets on the basis of the selected characteristics made it possible to highlight possible options for more perfect identification.

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Conflicts of Interest.

The authors declare no conflict of interest.

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Теоретичні та практичні аспекти ідентифікації клинкової зброї на прикладі багнета SG 98/05 до гвинтівки Маузера на основі металознавчого дослідження

Анотація. *У статті розглянуто дослідження фрагмента багнета з сильним пошкодженням металу, виявленого в м. Кременчук (Україна) в одному із каналів на околиці міста, неподалік річки Дніпро. Було виконано теоретичні дослідження для вивчення холодної зброї часів Першої світової війни та типології багнетів даного періоду, що дало змогу висунути припущення щодо ймовірної ідентифікації об'єкта як модифікованого багнета до гвинтівки Маузера. Металознавча експертиза ґрунтувалась на основі рентгенофлуоресцентної спектрометрії для визначення концентрацій елементів у пробі з очищеної частини клинка. Аналіз хімічного складу показав, що клинок виготовлено з загартованої вуглецевої сталі, легованої кремнієм, хромом, марганцем, нікелем і міддю. Результати вимірювань хімічного складу об'єкта відповідають сталі для відливок марки 55Л з середнім значенням твердості клинка 42 HRC. Технологія виготовлення відливку відповідає кінцю XIX – початку XX сторіччя із застосуванням конвертерного виробництва. Клинок багнета був підданий зміцнювальній термообробці у вигляді гартування та середнього відпуску. Металографічний аналіз показав, що досліджуваний фрагмент клинка зазнав корозійного розтріскування між кристалами або по тілу зерен, що свідчить про тривале перебування в мулистих відкладеннях. Ідентифікація досліджуваного об'єкта здійснювалася із застосуванням прикладних технологій на основі візуального огляду з описом стану збереження та порівнянні з результатами, відображеними в науковій періодиці; металознавчої експертизи; визначенні масогабаритних характеристик і їх відповідності оригіналу, у тому числі експериментальної реконструкції, що ототожнює збережений фрагмент з оригінальним кресленником у контрольних точках. Було виконано порівняння хімічного складу сталі клинка та сталі фірми "Haenel", які відрізняються концентрацією та додатковими легуючими* *елементами. Залишки відбитку клейма королівської монограми та відсутність полкового клейма стали основою пошуку за каталогами зареєстрованих багнетів. Це дозволило ідентифікувати досліджуваний об'єкт як частину німецького імперського модифікованого багнета зразка 1898/1905 до гвинтівки системи Маузера, який був виготовлений у період з 1915 по 1918 рр. Перспективи подальших досліджень вбачаються в збільшенні кількості металознавчих експертиз для більш точної ідентифікації знахідок.*

Ключові слова: *експертиза; визначення віку; археометалургія; експериментальна реконструкція; клеймо; "Бучер"*

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Теоретические и практические аспекты идентификации клинкового оружия на примере штыка SG 98/05 к винтовке Маузера на основе металловедческого исследования

***Аннотация**. В статье рассмотрены исследования фрагмента штыка с сильным повреждением металла, обнаруженного в г. Кременчуг (Украина) в одном из каналов на окраине города, недалеко от реки Днепр. Было выполнено теоретические исследования для изучения холодного оружия времен Первой мировой войны и типологии штыков данного периода, что позволило выдвинуть предположение о возможной идентификации объекта как модифицированного штыка к винтовке Маузера. Металловедческая экспертиза основывалась на основе рентгенофлуоресцентной спектрометрии для определения концентраций элементов в пробе с очищенной части клинка. Анализ химического состава показал, что клинок изготовлен из закаленной углеродистой стали, легированной кремнием, хромом, марганцем, никелем и медью. Результаты измерений химического состава объекта соответствуют стали для отливок марки 55Л со средним значением твердости клинка 42 HRC. Технология изготовления отливки соответствует концу XIX – начала XX века с применением конвертерного производства. Клинок штыка был подвергнут укрепляющей термообработке в виде закалки и среднего отпуска.*

Металлографический анализ показал, что исследуемый фрагмент клинка пострадал от коррозионного растрескивания между кристаллами или по телу зерен, что свидетельствует о длительном пребывании в илистых отложениях. Идентификация исследуемого объекта осуществлялась с применением прикладных технологий на основе визуального осмотра с описанием состояния сохранности и сравнении с результатами, отраженными в научной периодике; металловедческой экспертизы; определении массогабаритных характеристик и их соответствия оригиналу, в том числе экспериментальной реконструкции, что отождествляет сохраненный фрагмент с оригинальным чертежом в контрольных точках. Было выполнено сравнение химического состава стали клинка и стали фирмы "Haenel", которые отличаются концентрацией и дополнительными легирующими элементами. Остатки отпечатка клейма королевской монограммы и отсутствие полкового клейма стали основой поиска по каталогам зарегистрированных штыков. Это позволило идентифицировать исследуемый объект как часть немецкого имперского модифицированного штыка образца 1898/1905 к винтовке системы Маузера, изготовленного в период с 1915 по 1918 гг. Перспективы дальнейших исследований видятся в увеличении количества металловедческих экспертиз для более точной идентификации находок.

Ключевые слова: *экспертиза; определение возраста; археометаллургия; экспериментальная реконструкция; клеймо; "Бучер"*

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