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Research on early medieval weights: materials and technologies

Key words: weights, Rus, materials, technologies.
Cuvinte cheie: greutăți, Rusi, materiale, tehnologii.
Ключевые слова: гирьки, Русь, материал, технологии.

Tetiana Hoshko, Mykhailo Videiko
Research on early medieval weights: Materials and technologies
Early medieval trade in Europe, despite the spread of coins, was largely based on the need to weigh silver for payment. Not a single merchant who was engaged in eastern trade within the borders of Rus and the adjacent territories of the Khazar Khaganate did not do without a set of weights. A clear indication of the scale of this trade is the finds of the corresponding equipment, the comprehensive study of which can provide additional information about this vivid component of medieval history. In this work, we aim to highlight the issues related to the materials and technologies of creating weights found on the territory of Ukraine.

Tetiana Hoshko, Mykhailo Videiko
Cercetarea unor greutăți medievale timpurii: materiale și tehnologii
Comerțul medieval timpuriu în Europa, în pofida răspândirii monedelor, s-a bazat în mare parte pe nevoia de a cântări argintul pentru plată. Nici un comerciant, antrenat în comerțul estic în granițele Rusiei Kievene și a teritoriilor apropiate Khazarului nu s-a descurcat fără un set de greutăți. Un indiciu clar al amplorii acestui comerț sunt descoperirile echipamentelor corespunzătoare, al căror studiu de ansamblu poate oferi informații suplimentare despre această componentă vie a istoriei medievale. În această lucrare, ne propunem să evidențiem problemele legate de materialele și tehnologiile de fabricare a greutăților găsite pe teritoriul Ucrainei.

Тетяна Гошко, Михайло Видейко
Исследования раннесредневековых гирек: материалы и технологии
Раннесредневековая торговля в Европе, несмотря на распространение монет, в значительной степени держалась на взвешивании платежного серебра. Ни один торговец, занимавшийся восточной торговлей в пределах Руси и близлежащих территорий Хазарского каганата, не обходился без набора гирек. Ярким свидетельством масштабов этой торговли является находка соответствующего снаряжения, комплексное изучение которого может предоставить дополнительные сведения об этой яркой составляющей средневековой истории. В этой работе мы намерены осветить вопросы, связанные с материалами и технологиями создания гирек, найденных на территории Украины.

Research directions and characteristics of findings

Although the study of weights and weight systems of the early Middle Ages continues for more than a century, as experience shows, there is no such thing as too much information. Therefore, the introduction of new findings into scientific circulation has still not lost its relevance, as well as their in-depth study.

The use of weights for operations with silver or gold was one of the decisive factors that made trust in these tools. In the Kingdom of Sweden, King Olaf's mint masters in Sigtuna produced weights, which is evidenced, in particular, by finds of ceramic molds used in the process. According to A. Soderberg, these products were produced at least in workshops controlled by leaders who conducted trade affairs [Söderberg 2004, 116]. In view of this, it would be interesting to look at the weights that come from different territories of Rus and the nearest lands of the Khazar Khaganate adjacent to them, in order to establish the probable sources of their origin. For this, the typology and metrology of products are important, but in-

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formation about the manufacturing materials and applied technologies can be no less important. The amount of this information also weighs a lot on this path, so even random finds can come in handy in the end.

The collection of weights originates from finds made in the historical and geographical area of Ukraine and transferred during 2018-2022 to the Archaeological Museum of the Borys Grinchenko Kyiv University in Kyiv. The total number of studied samples was 62 pieces of products of various types and weights. They were found in different areas. This is mainly the Chernihiv region – 40 units; Kharkiv region – 12 units; Kyiv – 2 pcs.; Bila Tserkva, Kyiv region – 2 pcs.; Mykolaiv, Mykolaiv Region – 1 pc.; Khmelnytskyi region – 2 pcs.; Ternopil – 2 pcs.; and in the city of Kryzhopol, Vinnytsia region – 1 pc. The real conditions of the finds are unknown.

The products probably come from the settlements of the Middle Ages and can typologically be pre-dated within the 9^{th}-11^{th} centuries.

Some weights arrived in groups, several in each, and may be considered as "conditional complexes" in the future studies. The study of these things was carried out in two several directions, including materials and manufacturing technology, typology, metrology, marking. In this work, we aim to highlight the issues related to the raw materials and technologies of creating weights.

Research equipment and methodology

The chemical composition of the metal of all products was determined on an X-ray fluorescence spectrometer CEP-01 AAEC.412131.001, "ElvaX Light" modification with an extended range towards light elements. Normal spectrum was recorded at an emitter voltage of 35 kV and light spectra at a voltage of 12 kV. The collection time of each spectrum was 180 seconds. Registration of fluorescent radiation from the test sample was carried out using a semiconductor Si-Pin detector manufactured by Amptek (USA) with thermoelectric cooling. When examining the samples, the following operating modes of the X-ray tube (MOXTEK, anode material Pd) were set: voltage 45 kV, anode current in the range of 0–100 μA.Spectrometer sensitivity threshold for tin and nickel (Ni) – 0.05%, zinc (Zn) – 0.1%, lead (Pb) – 0.02%, silver (Ag) – 0.01%, stibium (Sb) – 0.01%, bismuth (Bi) – 0.008%, cobalt (Co) – 0.08%. The metal composition of the products was investigated on a mechanically cleaned surface of oxides. The numbers in the tables correspond to the item numbers in the illustrations (fig. 1-3).

Research results

Spheroid weights had a shell of non-ferrous metal and an iron core (fig. 1-2) Both the coating and the core of the products were investigated (Table 1-4). The following results were obtained. The

Fig. 1. Archaeological Museum of the Borys Grinchenko Kyiv University. Spheroid weights, № 19-41.

Table 1. Spectral analysis of heavies.

№ item	№ analyz.	Sn	Pb	Zn	Ag	As	Sb	Ca	S	P	alloy
20	2053	8,278	18,241	5,716	0,105	1,186	-	0,143	0,564	2,346	Cu-Sn-Pb-Zn-As
22	2055	9,051	17,274	3,982	0,151	0,881	0,065	0,827	0,489	4,073	- // -
35	2067	23,68	9,434	5,517	0,156	1,543	0,055	-	0,256	3,859	- // -
21	2054	3,453	11,46	4,528	0,399	0,595	-	0,126	0,357	2,934	Cu-Sn-Pb-Zn
30	2062	2,864	17,254	5,052	0,107	0,729	-	0,239	0,571	2,72	- // -
33	2065	3,854	14,589	2,805	0,13	0,652	-	0,214	0,467	1,34	- // -
44	2076	2,592	9,814	5,135	0,247	0,524	0,069	1,369	0,281	13,132	- // -
45	2077	6,665	6,647	7,313	0,107	0,47	0,152	0,259	0,201	1,171	- // -
46	2078	1,471	19,523	3,933	0,093	0,404	0,049	0,474	0,514	2,711	- // -
50	2082	2,249	19,091	3,389	0,109	0,79	0,042	0,196	0,694	3,803	- // -
53	2085	4,362	18,178	3,713	0,135	0,449	0,056	0,373	0,647	3,974	- // -
54	2086	5,283	16,12	1,555	0,106	0,72	-	0,374	0,453	3,405	- // -
56	2088	0,838	28,204	2,997	0,104	0,472	0,044	0,071	0,786	2,169	- // -
27	2059	1,847	5,498	2,915	0,105	0,478	0,046	0,56	0,283	4,028	- // -
48	2080	0,884	19,664	3,256	0,159	0,446	0,045	0,098	0,694	1,574	- // -
37	2069	7,587	4,418	0,566	0,077	0,784	0,079	0,203	0,103	2,017	- // -
19	2052	4,717	15,64	2,119	0,119	-	0,057	0,673	0,345	3,446	- // -
28	2060	1,149	13,154	3,155	0,124	0,14	0,047	0,155	0,409	2,596	- // -
31	2063	7,851	15,296	2,617	0,078	-	0,032	0,651	0,547	3,837	- // -
38	2070	2,466	12,576	6,451	0,11	0,18	0,032	0,043	0,393	1,419	- // -
39	2071	5,071	12,753	6,453	0,406	0,391	0,068	0,353	0,387	3,107	- // -
41	2073	0,951	20,362	3,927	0,109	-	0,046	-	0,629	3,164	- // -
47	2079	14,06	26,847	6,629	0,133	0,18	-	1,118	0,51	3,1	- // -
34	2066	0,966	4,056	5,921	0,081	0,315	0,059	0,125	0,149	2,172	- // -
58	2090	2,554	6,855	4,114	0,168	0,371	-	-	0,242	2,185	- // -
59	2091	5,423	6,464	5,77	0,144	-	-	0,533	0,166	1,278	- // -
25	2057	0,604	3,034	0,691	0,152	0,209	0,094	1,052	0,098	3,577	- // -
51	2083	2,08	27,874	0,358	0,09	0,022	0,027	0,224	0,816	0,881	Cu-Sn-Pb
29	2061	-	15,228	7,278	0,078	-	0,033	0,16	0,596	1,968	Cu-Pb-Zn
36	2068	0,101	10,34	4,735	0,122	0,228	-	-	0,287	0,567	- // -
40	2072	0,48	17,94	6,905	0,113	-	-	0,858	0,65	6,742	- // -
49	2081	0,225	5,776	6,791	0,108	0,12	-	0,051	0,205	1,125	- // -
52	2084	0,121	5,743	6,288	0,142	0,154	0,057	0,192	0,142	3,422	- // -
55	2087	0,508	9,105	7,283	0,104	0,368	-	0,125	0,255	1,68	- // -

57	2089	0,198	24,88	1,595	0,115	-	0,03	1,225	1,079	6,315	- // -
62	2094	0,299	29,648	2,866	0,092	-	0,037	1,046	1,186	8,713	- // -
23	2056	-	18,033	6,187	0,062	1,325	0,039	0,66	0,66	4,39	Cu-Pb-Zn-As
32	2064	0,14	7,8	4,412	0,081	1,51	-	0,112	0,309	1,347	- // -
42	2074	0,661	4,71	12,99	0,121	2,299	0,337	0,392	0,173	4,059	- // -
60	2092	0,162	25,735	4,384	0,027	0,628	0,037	0,495	0,794	2,126	- // -
61	2093	0,031	6,698	11,353	0,075	0,604	0,056	0,148	0,318	1,675	- // -

analysis of the coating composition of flattened spheroid stones showed that only one copy belongs to lead-tin bronze (Cu-Sn-Pb), and 8 copies belong to the so-called triple brasses (Cu-Pb-Zn). The vast majority is represented by multi-component brasses (Cu-Sn-Pb-Zn, Cu-Sn-Pb-Zn-As, Cu-Pb-Zn-As).

Alloys similar in chemical composition could be obtained as a result of multiple remelting of secondary raw materials of various origins.

Taking into account the huge number of finds of scrap bronze and brass products, which comes from the cultural layer of early medieval settlements фтв сшешуі, this conclusion seems well-founded.

The results of the above analysis generally coincide with the conclusions of other researchers, who noted a high percentage of multicomponent alloys on monuments of the X – the first half of the XI century. In products originating from the settlement and burial sites of the Rus times, such as Pskov, Stara Ladoga, Zalakhtovya, and the mounds of the Izhora Plateau. It was established that at the beginning of the second half – the end of the XI century. similar multicomponent mixtures are present in approximately equal proportions [Eniosova, Mitoian, Saracheva 2008, 133-136].

A small cubo-octahedroid weight № 46 (fig. 3) is quite rare. It comes from the territory of Chernihiv region. The dimensions of the sides are 10×10×10 mm, weight 3.31 g. It is made of iron and coated with a very thin and invisible layer of copper alloy (Table 2), different from that used on spheroid picks. Perhaps the method of "coppering" this heavy was different. One of the flat sides is heavily inscribed with two dot

Table 2. Spectral analysis of weight No. 46.

№ item	№ an.	Sn	Pb	Zn	Ag	As	Sb	Ca	S	P	alloy
46	2078	1,471	19,523	3,933	0,093	0,404	0,049	0,474	0,514	2,711	Cu-Sn-Pb-Zn

Table 3. Spectral composition of weight No. 3.

Lab. №	Sn	Pb	Zn	Ag	Sb	As	Fe	K	Cl	S	P	alloy
2034	32,533	3,123	0,241	0,166	0,496	0,546	0,099	0,259	0,219	0,097	0,163	Cu-Sn-Pb

Table 4. Spectral analysis of iron weights and a spheroid weights.

№ item	lab №	Ti	Sn	Pb	Ag	Sb	Cr	Fe	Ni	Co	Cu	Mn	Ta
1	**2032**	-	0,418	**98,79**	-	-	-	**0,255**	<0,015		0,081	<0,034	0,128
3	**2033**	-	-	**98,92**	-	-	-	**0,537**	<0,019	-	0,087	-	0,121
4	**2035**	-	-	**99,47**	-	-	-	**0,251**		-	0,064	<0,048	0,073
5	**2036**	-	0,016	**99,41**	0,027		-	**0,339**	-	0,064	0,287	0,129	0,147
6	**2037**	<0,126	0,481	**97,28**	0,033	0,183	<0,053	**1,222**	-	<0,024	<0,019	-	0,165
13	**2047**	<0,145	0,17	**98,95**	-	0,082	<0,057	**0,387**	-	-	0,074	-	0,097
14	**2048**	<0,09	0,591	**98,46**	-	<0,054	-	**0,618**	0,021	<0,026	0,227	<0,051	<0,041
15	**2049**	-	<0,027	**99,35**	-	-	-	**0,442**	-	trace	0,066	-	trace

Fig. 2. Archaeological Museum of the Borys Grinchenko Kyiv University. Spheroid weights, № 42-62.

markings that may have been placed on a previously hammered line (fig. 4,1). On the opposite side, there is an indistinct straight dashed line.

Rare is another well-preserved weight no. 3, found near the city of Kryzhopol in the Vinnytsia region. It is parallelepipedal in shape, made of tin-lead bronze (Table 3). The dimensions of this product are 18×18×11-12 mm (fig. 3). Along its perimeter, on all side surfaces, a seam is clearly visible, very similar to the one left as a result of casting on a wax model. 8 pieces are placed on one of the ribs. One of the wide surfaces is punched with a sign similar to the mirror image of the uppercase Greek letter lambda (λ). In the numbering system using letters, it has a value of 30. Interestingly, the weight of the kettlebell is 30.79 g, which is exactly on the mark.

An iron weight in the form of a ball with one flattened side (fig. 3, No. 26). Analyzing the chemical composition of these products and the non-coppered spheroid rock, we see a very similar metal in composition (Table 4). This gives us an opportunity to claim nearby ore sources. A rather high content of manganese in iron indicates bog ores. We will remind that these weights were found in the territory of the Chernihiv region, which is rich in deposits of such ore. This is confirmed by the found remains of the iron mining process in the form of slag and slag in many Rus settlements. Thus, there are reasons to talk about the probability of local production of these weights.

Small iron weights (fig. 3) of parallelepiped shape come from Kharkiv (№ 7-12) and the Kharkiv region. (№ 17-18). This is the territory of distribution of monuments of the Saltovo-Mayak culture, with which they are probably connected. Surface-corroded finds were mechanically cleaned after discovery, so small weight losses are possible.

During the study of spheroid type weights, our attention was drawn to the technology of their "coppering", described at one time by the Scandinavian researcher A. Sodersberg [Söderberg 2004]. Traces of this production are found in the form of disposable ceramic shells [Söderberg Olausson 1997]. The technology is as follows: the forged iron core is covered with brass plates, tightly wrapped in a linen cloth and greased with clay. After the clay casing has dried, the mold is placed in the fire and kept at a temperature of 950°C for some time so that the metal melts. This form is disposable, at the end of the process it must be broken in order to get the finished product. Fragments of similar forms (or packaging material according to A. Söderberg) with fabric prints are found among the remains of workshops or mints in many Scandinavian cities of the 9^{th}-13^{th} centuries.

It was interesting to try to reproduce this technology and find out how complicated it is. The

Fig. 3. Archaeological Museum of the Borys Grinchenko Kyiv University. Different weights, № 1-18; 26, 46.

corresponding experiments were carried out during the archaeological expedition of the National Institute of Archeology in 2021. The purpose of the experiment was to reproduce the technology of coating an iron core with a heavy non-ferrous metal [Goshko, Videiko 202, 10-11, fig. 4-5]. In this case, the task of matching the core to a certain weight was not set. Therefore, a small ball from a ball bearing was used. It was preliminarily cleaned from the chrome coating, and slightly flattened on both sides by forging to give it the appropriate shape. Next, the cult was covered with fragments of brass and wrapped in a skull cloth. The package is smeared with clay, dried.

When the form was taken out of the fire, cooled and broken, a moldy fabric and a copper-plated hill were found inside [Goshko, Videiko 2021, fig. 4]. However, uniform and even coating of the surface of the iron core was obtained only on half of the product. The other part was covered with tubercles. There can be two explanations for such a result: the first is that the mold should have been actively pumped after removing it from the fire so that the metal was evenly distributed over the surface of the iron core. The second, perhaps, is unburnt tissue inside the mold, which could also interfere with the free distribution of brass over the surface of the iron core.

The conducted research showed that even with general ideas about the applied technology, its reproduction with obtaining a positive result requires skills and experience, especially taking into account the requirements for compliance with the standard weight of products. The experience gained also fully confirms the researchers' conclusions made earlier regarding the high level of skill and experience of artisans producing spheroid weights.

Analysis of research results

A variety of materials and technologies were

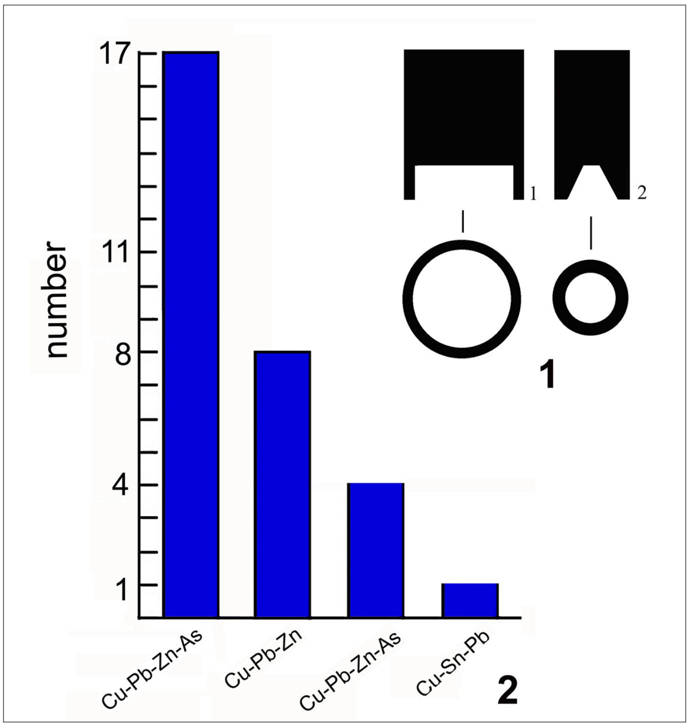

Fig. 4. Archaeological Museum of the Borys Grinchenko Kyiv University. 1 – forms of punches for coining signs; 2 – Four groups of copper-based metal alloys, used for weights producing. The vertical axis indicates the number of artefacts within each group.

used to make the studied weights in the early Middle Ages. The most complex products were spheroid weights. Iron and brass were used in their manufacture. The source of the brass, as the analyzes showed, in this case could well be scrap metal – secondary raw materials. The study of the iron component may indicate the use of local swamp ore, at least for finds from the territory of the Chernihiv region. Taking into account that most of the finds come from there, it is precisely in this region that the heavy use falls, so the need for these products there could have been comparatively the greatest.

However, the conclusion about the local production of spheroid weights will require additional justification, including the study of a larger number of samples. In addition, there are still unknown traces of production in the form of fragments of ceramic forms, which were used in the creation of shells of iron cores.

Local production of lead weights seems more likely. The study of their chemical composition indicates the probability of using polymetallic ores common in the Nagolny Ridge. In addition, these lead products are technologically much simpler than spheroid weights.

The next stage of the study of weights will be the study of their metrology and the signs engraved on them.

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