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THE METALLOGRAPHIC CHARACTERIZATION OF CAST PRODUCTS ON THE EXAMPLES FROM THE MIDDLE AGES

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1. Introduction

This work presents the metallographic properties results of few copper objects from the middle ages. In history as well as today, non-ferrous alloys are often used where copper and its alloys take their prominent pace; it is worth mentioning here the main groups of copper alloys: bronzes, brasses, alloyed copper and copper-matrix alloys for special requirements. The physico-chemical and technological properties of casting copper alloys determine their quality and application. Besides these properties are strongly affected by metallurgical process for obtaining copper, alloying additions and control of melting, refining and casting processes. To the advantageous properties of copper alloys should be included the high resistance to corrosion, therefore the discovered artifacts are usually in good condition. Also, artistic value and availability of raw materials determine the use of copper alloys for casting usable and ornamentals products. [1-4]

Historical research of copper alloys bring information about the old metallurgy and foundry technology, quality of raw material and the ability to shape physico-chemical and technological properties of alloys through the influence of alloying elements. Part of these studies is the analysis of metal relics from the Puck conducted at the Faculty of Foundry AGH in collaboration with the University of Warsaw. Medieval European cities were centers of trade and production of metal products [5]. Also on terrain of Puck, the manufacturing activities can be confirmed basing on the metal findings. The aim of this study was to identify and systematize copper alloys used in the Middle Ages, on the basis of historic artifacts from Puck. The chemical composition analysis and microstructure observation were carried out. Researches are the first stage of preparing to an experiment regarding reconstruction the medieval alloys in order to enrich their characterization.

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2. Experimental

The artifacts were obtained during archaeological research at Market Square in Puck. During the studies, the macroscopic observation of metal objects in order to evaluate their conservation status, production techniques and destination were performed. Only the non-destructive methods were applied to characterize the samples: chemical composition was established by X-ray fluorescence spectroscopy (XRF), the microstructure was analysed using optical microscopy (OM) and scanning electron microscopy conducted with energy-dispersive X-ray spectroscopy (SEM-EDS).

3. Results and discussion

Analysis of chemical composition showed that all copper alloys were applied in production of metal products (Figs. 1-2, Tab.1). In the alloys, have been identified intentional alloying additions as Sn, Zn, Pb and natural additions difficult to remove by ancient metallurgists, which nowadays can be regarded as a trace of origin and ancient technology such as Fe, Sb, As, Ni and others.

Fig. 1. Macrostructure of the artifacts from Puck, 6,7 x

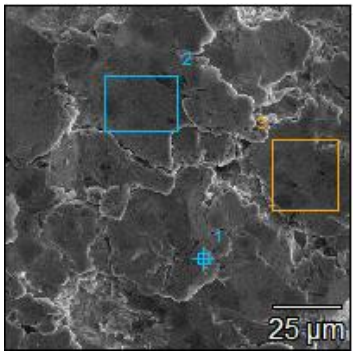

Table 1. The chemical composition's results in the microareas by means of SEM-EDS.

Elements (wt. %)	Fe	Ni	Cu	Zn	Sn	Pb
Pt 1	0.42	0.00	89.37	5.93	3.29	0.00
Pt 2	0.29	0.75	82.22	5.07	3.61	6.07
Pt 3	0.15	0.00	80.72	3.49	4.06	9.58

Fig. 2. Microstructure of the artifacts from Puck with measurement points selected

4. Conclusions

Macro and microscopic studies made it possible to assess production technologies, among which dominated the casting technique. On the basis of chemical composition, a presence of various metals and alloys in the studied group the artifacts was identified including copper, binary alloys: Cu-Sn, Cu-Zn and multi-component alloys: Cu-Zn-Sn, Cu-Pb-Sb, Cu-Pb-Zn-Sn, Cu-Pb-Sb-Sn, Cu-Pb-Sb-As. The test results will allow to compare the chemical composition of alloys from Puck with existing researches and make up the base for analyzes of historical alloys.

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References

1. Rzadkosz, S. (2013) *Odlewnictwo miedzi i jej stopy*. Krakow: WN „Akapit".
2. Rdzawski, Z. (2009) *Miedź stopowa*. Gliwice: Wydawnictwo Politechniki Śląskiej.
3. Romankiewicz, F. (1998) *Krzepnięcie miedzi i jej stopów*. Poznań - Zielona Góra.
4. Kwak, Z., Garbacz-Klempka, A., Kolczyk, J. (2013) Jewellery-making using investment lost wax casting technology inspired by old motifs: *Archives of Foundry Engineering*, Vol. 13, No. 3 (2013), 95-100.
5. Głowa W., Garbacz-Klempka A., (2010) Z badań nad wytwórczością średniowiecznych ozdób, Krzysztofory, 28 (2), 97-110.