Homogeneity study of modern bronzes for artistic castings using PIXE and PLP

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Metal casting is the most efficient way of shaping metals both for industrial purposes, as well as in art modeling. However, when casting an art model in metal, focus is on shape and form, and quality of a cast is often neglected. Therefore, artistic casts may vary in composition and structure, and often exhibit poor homogeneity. Inhomogeneity in composition decreases mechanical properties of a cast alloy but also has a negative affect on corrosion resistance of alloy due to formation of anodic and cathodic places. These can lead to very dangerous local (galvanic) corrosion.

Modern bronzes, cast in typical art foundries today, often show a high degree of inhomogeneity and various compositions due to many different casting methods in use and because of often very unrefined temperature control systems in processes of melting and solidification.

In order to examine distribution of Sn as a major alloying element and Zn, Pb and Fe as trace elements, larger area line scans were performed using PIXE (proton induced X-ray emission). The areas which have showed large scale inhomogeneities were subsequently examined by the means of Potentiodynamic linear polarization measurements, which were able to confirmed higher potential and current appearance for those regions.

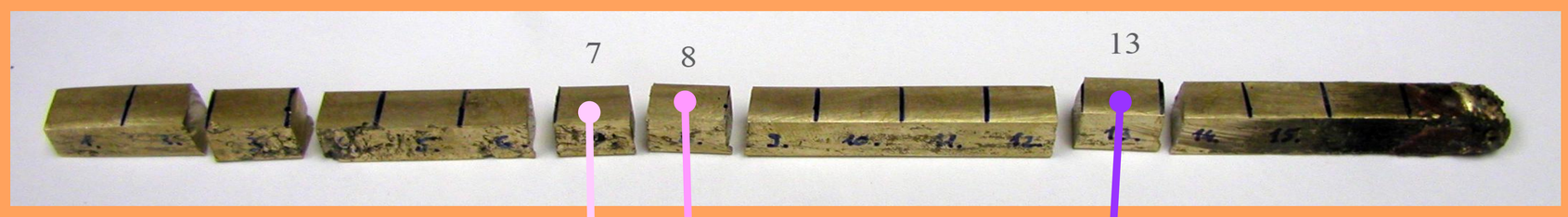

Fig. 1. Cast bronze sample used in testing.

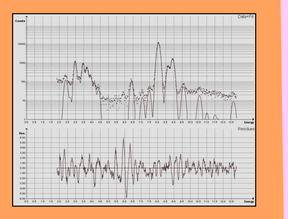

Fig. 2.

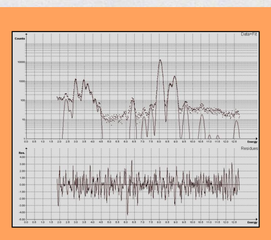

Fig 3.

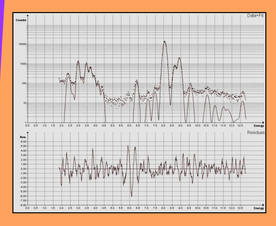

Fig. 4.

Fig. 2,3,4, PIXE spectrograms for parts 7, 8 and 13 of cast bronze sample.

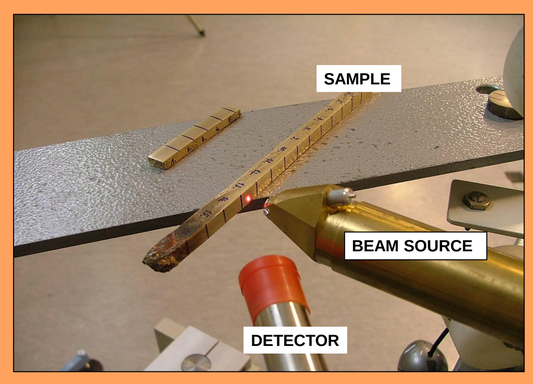

Fig. 5. Device setup for PIXE measurements.

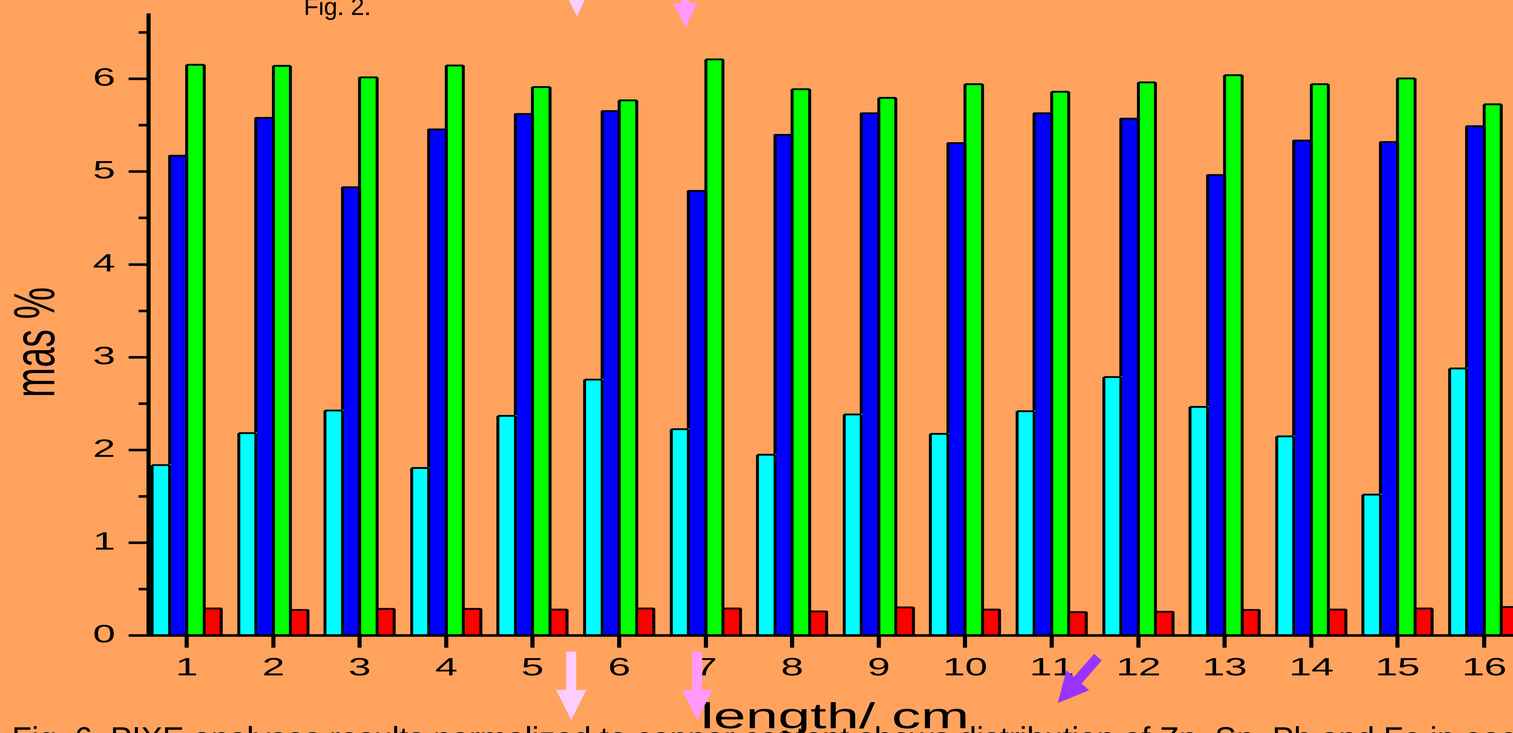

Fig. 6. PIXE analyses results normalized to copper content shows distribution of Zn, Sn, Pb and Fe in each marked part of sample. Sample parts 7,8 and 13 have been cut out and used for electrochemical measurements due to their variation in composition (inhomogeneity).

Table 1. Distribution of major and minor elements in cast bronze sample on part 7, 8 and 13.

Mass %	Part 7	Part 8	Part 13
Sn	4,79	5,39	4,96
Zn	6,21	5,89	6,04
Fe	0,29	0,26	0,27
Pb	2,23	1,95	2,46

Fig. 7. Device setup for potentiodynamic measurements

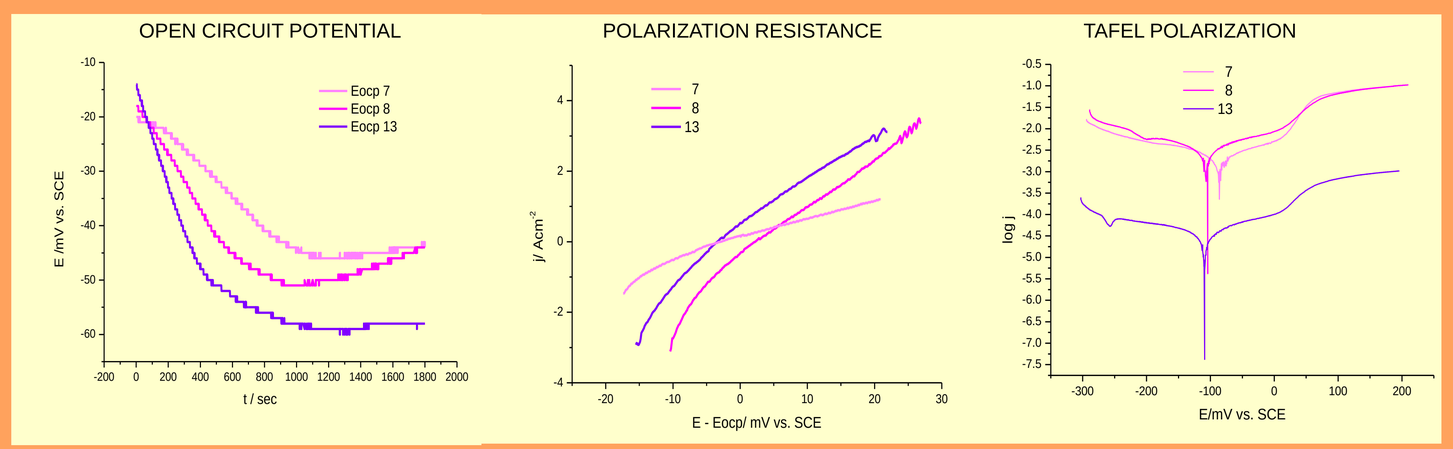

Fig. 8. Potentiodynamic linear polarization measurements shows contradictory results. While in polarization resistance measurements part 7 shows better corrosion behavior,Tafel polarization results shows better corrosion behavior of part 13 (smaller corrosion rate).

Table 2. Corrosion parameters calculated from linear polarization mesurements.

Parameter	Sample 7	Sample 8	Sample 13
Polarization resistance, *R*p / kΩ cm^2	63,22	147,59	149,55
Corrosion potential, *E*cor /mV	-73,45	-111,66	-110,13
Corrosion current, *j*cor / A cm^{-2}	2,387*10^{-6}	3,410*10^{-6}	4,109*10^{-8}
Anodic Tafel slope, *b*a /mV dek^{-1}	244,43	275,27	280,28
Chatodic Tafel slope, *b*k /mV dek^{-1}	385,59	244,99	445,05
Corrosion rate, *r* / μg cm^{-2} h^{-1}	8,20	11,82	0,14

CONCLUSION:

PIXE analysis shows large scale inhomogeneity in examined cast-bronze sample in matter of four investigated elements, especially in areas marked as 7, 8 and 13. However, corrosion parameters calculated from polarization measurements don't give clear and definite correlation between variations in compositions and corrosion behavior of three examined parts.

EXPERIMENTAL: Cast bronze sample (17 cm long) from Art Foundry of Academy of Fine Arts in Zagreb was divided in smaller parts (length of 1cm) and every part was examined in composition inhomogeneity using PIXE. PIXE setup was: 2 mm large beam extracted in air through a 50μm thick Al window; beam energy- 2MeV; sample distance- 0,9 cm; Si(Li) detector; distance from detector-1,4 cm (fig.5). PIXE results were analyzed by Gupix software. Subsequently , three parts of the sample that showed larger inhomogeneity in concentration were embedded in epoxy resin and prepared for electrochemical measurements: Open circuit potential, Linear polarization near OCP, and Tafel Polarization.

Literature:
[1] Gamaz. F., Chaves C., Watjen U., Nucl. Inst. and Meth. B150 (1999) 559-564
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