

# COMPARISON BETWEEN TRIBOCORROSION BEHAVIOUR OF ALUMINIUM BRONZE AND LEADED TIN BRONZE IN SIMULATED SEA WATER

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## ABSTRACT

This paper summarises the main findings of the presentation given in NordTrib2018 conference held in Uppsala, Sweden, on 18-21 June 2018. The presentation concentrated on the comparison of the overall tribocorrosion behaviour of aluminium bronze and leaded tin bronze, the original pieces of research of which have been reported elsewhere. Here, the main results are presented and evaluated.

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## INTRODUCTION

Aluminium bronze and leaded tin bronze are extensively used in tribological applications, for example bearings. Given that these alloys are used in a range of industry sectors, it is likely that there are cases where, under mechanical contact to a solid counterbody in a relative motion, they are also subjected to a corrosive environment. In such cases, tribocorrosion behaviour of the alloys becomes of interest. However, the two alloys differ with respect to their properties: aluminium bronze has a good corrosion resistance and high strength, while leaded tin bronze is characterised by an excellent lubricity and therefore suited for conditions with interrupted lubricant supply, moderate loads and high speeds. On this basis, differences in their tribocorrosion behaviour are expected. Lead is in the REACH restricted substances list, thus alternative alloy solutions are sought for leaded tin bronze. This work compares the tribocorrosion behaviour of aluminium bronze and leaded tin bronze in simulated seawater, in order to identify whether aluminium bronze

could replace leaded tin bronze in some foreseen operation conditions.

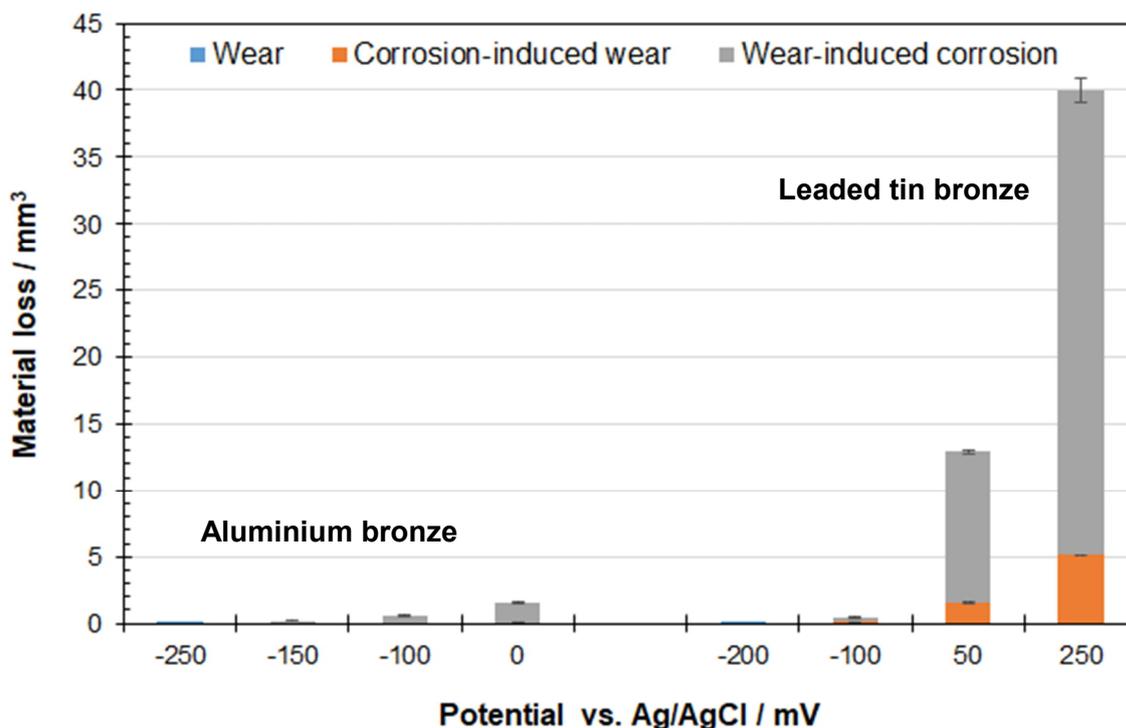
## EXPERIMENTAL

The alloys examined with respect to microstructure and tribocorrosion behaviour were aluminium bronze CuAl10Fe5Ni5 and leaded tin bronze CuSn10Pb10. Disc specimens of the diameter of 40 mm and the thickness of 6 mm were machined of the alloys. An alumina ball of 10 mm in diameter was used as the counterbody in a pin-on-disc tribometer (Anton Paar Tritec) and applied with the normal load of 10 N (~900 MPa contact pressure) during the tests run until the sliding distance of 1440 m at the speed of 0.2 m/s. The tests were performed in an electrochemical cell included in the tribometer and filled with 3.5 wt.% NaCl solution. The disc specimen fastened in a specimen holder in the bottom of the cell was the working electrode in the electrochemical measurements, with platinum ring at the cell periphery acting as a counter electrode and Ag/AgCl being the reference electrode. The tests were run at four potentials: one cathodic

potential and three anodic potentials, and under the two types of conditions: under the contact to the alumina counterbody and in the absence of the counterbody, in order to evaluate the synergy between the wear and corrosion processes. More experimental details and, e.g., how the synergy was defined, may be found elsewhere [1, 2]. In the case of aluminium bronze, the selected potential levels were -250, -150, -100 and 0 mV vs. Ag/AgCl, whereas the corresponding values in the case of leaded tin bronze were -200, -100, 50 and 250 mV vs. Ag/AgCl. The behaviour analyses were conducted based on current density records during potentiostatic experiments, collected friction coefficient data and post-experiment characterisation by scanning electron microscopy (SEM) coupled with energy-dispersive spectrometry (EDS) and profilometry.

## RESULTS

Both alloys had a multi-phase microstructure: aluminium bronze contained  $\alpha$ -Cu, Fe<sub>3</sub>Al, Ni<sub>3</sub>Al and FeAl phases, whereas leaded tin bronze involved the following phases: Pb, Cu<sub>0.97</sub>-Sn<sub>0.03</sub> Cu<sub>0.93</sub>-Sn<sub>0.07</sub>. Exposure of aluminium bronze to the 3.5 wt% NaCl solution under anodic conditions first introduced the development of Cu<sub>2</sub>O but with further increase in potential (oxidizing capacity) the selective dissolution of the  $\alpha$ -Cu phase became the dominant surface process. Under the mechanically loaded counterbody, aluminium bronze underwent plastic deformation and abrasive wear, and the interactions between wear and corrosion grew in importance with increase in potential. The main synergy mechanism was called wear-induced corrosion (Fig. 1), referring to the essential electrochemical nature of the material loss which was facilitated by wear (or in a more general level: tribology).



*Figure 1. Material losses for aluminium bronze and leaded tin bronze in 3.5 wt.% NaCl under the contact pressure of ~900 MPa*

Here, wear-induced corrosion was due to the removal of weakened selectively dissolved layer and the exposure of fresh surface for further attack. In the case of leaded tin bronze, exposure to 3.5 wt.% NaCl caused the evolution of a layer of corrosion products, the compound selection of which was dependent on the potential level. Just above the corrosion potential, Cu<sub>2</sub>O was the primary corrosion product detected, but with increase in potential, also CuCl and Cu<sub>2</sub>(OH)<sub>3</sub>Cl formed. Under the contact to the counterbody, similarly to the case of aluminium bronze, the corrosion product layer was removed, with plastic deformation of the alloy underneath being detected. The main difference to aluminium bronze was the significant acceleration of the anodic dissolution of the alloy, causing much higher material loss rates, Fig. 1. Wear-induced corrosion was also here the main degradation mechanism, followed by corrosion-induced wear.

The total material losses for the two alloys as a function of potential are shown in Fig. 1. It is evident that with increase in potential, i.e., oxidizing capacity of the environment, the material losses grew due to strengthening interactions of wear and corrosion. The overall material losses were much higher for leaded tin bronze than for aluminium bronze, due to the significant contribution of wear-induced corrosion. Thus the results from tribocorrosion experiments suggest that aluminium bronze could be considered for the replacement of leaded tin bronze in some applications subjected to tribocorrosion. However, the possible dissimilar requirements for the two alloys under pure wear or corrosion situations should be kept in mind, e.g., concerning the need for or type of lubrication.

## CONCLUSIONS

Tribocorrosion behaviour of aluminium bronze and leaded tin bronze has been examined and compared. Under identical test conditions, total tribocorrosion losses were much greater for leaded tin bronze than for aluminium bronze. The main degradation mechanism for both alloys was wear-induced corrosion, yet dissolution rate in aluminium bronze was much lower than in leaded tin bronze. Under tribocorrosion conditions, leaded tin bronze could therefore be considered to be replaced by aluminium bronze, yet the performance requirements by pure wear and pure corrosion occurring separately should be carefully taken into account (e.g., lubrication).

## REFERENCES

- [1] E. Huttunen-Saarivirta, E. Isotahdon, J. Metsäjoki, T. Salminen, L. Carpén, H. Ronkainen, Tribocorrosion behaviour of aluminium bronze in 3.5 wt.% NaCl solution. *Corrosion Science* 144, 2018, 207-223. <https://doi.org/10.1016/j.corsci.2018.08.058>
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