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FINAL REDOXIDATION OF COPPER AND BRONZE ALLOYS EXPERIMENTAL AND INDUSTRIAL ANALYSIS

Abdurafiqov Behzod Anvarjon o'g'li
Assistant, Registrar's Office Manager, Almalyk branch of TSTU abdurafikovbekhzod@gmail.com
Raximboyev Sherzodjon Ikrom o'g'li
Assistant, Registrar's Office Manager, Almalyk branch of TSTU
sherzodjonraximboyev2@gmail.com

Abstract

This thesis presents an experimental and industrial study of the final redoxidation of copper and bronze alloys. Oxygen pickup during reoxidation was measured under laboratory and industrial conditions. The effects of oxygen on microstructure, mechanical strength, and electrical conductivity were analyzed.

Introduction

Redoxidation is a common issue in non-ferrous foundries, leading to oxide inclusions, porosity, and reduced properties. While theoretical models exist, experimental validation is required to understand real-world behavior. This research investigates reoxidation in copper, tin bronze, aluminum bronze, and silicon bronze, both in laboratory furnaces and industrial foundries.

Materials and Methods

Copper and bronze alloys were melted in induction furnaces equipped with precise temperature control (±3 K) under protective argon and nitrogen atmospheres to minimize uncontrolled oxidation. Prior to experiments, crucibles were preheated to remove residual moisture. Following deoxidation treatments, melts were deliberately re-exposed to oxidizing atmospheres (air and controlled O_2/Ar gas mixtures) for fixed durations ranging from 30 seconds to 10 minutes, allowing systematic study of final reoxidation behavior.The dissolved oxygen content in solidified samples was analyzed using a LECO TCH600 inert gas fusion analyzer, with a detection limit of 2 ppm, ensuring high precision in oxygen quantification. For reliability, three measurements were performed for each sample, and the average value was reported with a standard deviation. Microstructural investigations included optical microscopy (etched and polished specimens) to observe general grain morphology and oxide distribution. Detailed characterization of inclusions and oxide phases was performed using scanning electron microscopy (SEM) with energy dispersive spectroscopy (EDS) to determine chemical composition, and X-ray diffraction (XRD) to identify crystalline oxide phases such as Cu_2O, SnO_2, Al_2O_3, and SiO_2. In selected cases, electron backscatter diffraction (EBSD) was used to study inclusion–matrix interactions and grain boundary *effects.*

Mechanical properties were evaluated by tensile testing (ASTM E8 standard) to determine ultimate tensile strength, yield strength, and elongation, and by Vickers hardness measurements with a 5 kgf load. To assess functional performance, electrical conductivity was measured using a four-point probe method and expressed as %IACS (International Annealed Copper Standard). Results were compared with reference values from industrially produced copper and bronze alloys to assess the influence of reoxidation on end-use performance. Complementary fractography studies were carried out on fracture surfaces after tensile testing using SEM to identify failure mechanisms, particularly the role of oxide inclusions in initiating cracks. In addition, density measurements were performed by the Archimedes method to evaluate porosity associated with gas absorption during reoxidation. This integrated methodology—combining thermodynamic and kinetic modeling, precise oxygen measurement, microstructural characterization, and mechanical/electrical property evaluation—enabled a comprehensive understanding of how final reoxidation affects the quality, performance, and reliability of copper and bronze alloys.

Results and Discussion

Pure copper showed oxygen pickup from 25 ppm to 115 ppm within 2 minutes of air exposure. Bronzes showed even higher oxygen absorption, with silicon bronze reaching 170 ppm. Microstructural analysis revealed Cu2O, SnO2, Al2O3, and SiO2 inclusions, which caused porosity and reduced ductility. Tensile strength decreased by 20–35% across all alloys. Electrical conductivity in pure copper decreased from 99% IACS to 82% IACS after reoxidation. Industrial samples exhibited similar degradation, confirming laboratory trends.

Conclusion

Final redoxidation has severe effects on copper and bronze alloys, reducing mechanical and electrical properties. Silicon bronze was found most sensitive to oxygen pickup. The results highlight the need for strict atmosphere control during melting and casting to minimize defects.

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