Effect of Mo and B Additives on Hardness and Wear Resistance of Cu-Ni Alloy

KEYWORDS:
Cu-Ni alloy, hardening, wear resistance, molybdenum, boron

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INTRODUCTION: Metal corrosion in marine environment is a major issue for the safety of maritime transportation and petroleum production from ocean, which leads to a huge cost for facility maintenance and replacement [1]. Different materials and anti-corrosion techniques are developed to reduce the cost and improve the durability of relevant facilities. Due to its corrosion resistance and modifiable mechanical properties, Cu-Ni alloy has found a wide variety of applications especially in the marine environment [2-5]. Cu alloys are electrically conductive and their non-sparking and non-magnetic properties make them suitable for working in explosion risk environments, e.g., oil refineries, chemical plants and underground mining [6]. Copper can be strengthened by alloying elements. Nickle is one of common elements used as an alloying element to increase the mechanical strength and corrosion resistance of copper. Though Cu alloys have higher corrosion resistance, their mechanical strength is still lower. It is highly desired if the mechanical strength and wear resistance of Cu-Ni alloy can reach levels comparable to those of steel. In this study, we modified Cu-Ni alloy by adding elements of Mo, B, and their combinations with the attempt to increase hardness and wear resistance of Cu-Ni alloy to considerably higher levels.

METHODS: Metal powders of Cu, Ni, Mo and B were weighed designed combinations to make samples an arc melting furnace. The samples were re-melted in the furnace three times to increase their microstructural homogeneity. Cu-Ni and its modified samples with atomic concentrations of 2% B, 2% Mo, 2% B and 2% Mo, 10%B and 10% Mo, respectively, were fabricated. The samples were then annealed at 600℃ in an Ar atmosphere for 4 hours. Surfaces of the samples were polished with sandpapers of 60, 80, 400,600, 800 and 1200 grit and finally by 1-micron alumina polishing paste. Scanning electron microscopy, optical microscopy and X-Ray diffraction techniques were used for characterization. Rockwell hardness was measured using a universal hardness testing machine using a 1/16” ball with a load of 100 kg. Four different regions of each sample were selected and tested, based on which average values were obtained. Wear resistance of the samples were evaluated using a pin-on-disk wear tester at a sliding speed of 1.00 cm/s and under a load of 10 N in air and 3% NaCl solution, respectively. Wear track was analyzed by optical profilometry and SEM. Wear volume loss was determined from the wear track.

RESULTS AND DISCUSSION: It was demonstrated that the Mo and B additives were effective in strengthening the Cu-Ni alloy as shown in figure 1, while retaining desired corrosion resistance. In particular, the combination of Mo and B additives was more effective than a single additive to harden the alloy, leading to considerably elevated wear resistance. The modified Cu-Ni alloy samples show their hardness comparable to that of a normalized low carbon steel (ASTM A 109). With increasing Mo and B additives, hardness and wear resistance were increased considerably. As shown in figure 1 (b), the volume loss of the Cu-Ni alloy with, e.g., 2%B and 2%Mo, caused by wear was reduced by 35% and 55% when tested in air and 3% NaCl solution, respectively. The resistance of this sample to wear in air is still lower than that of the low-carbon steel, which is ascribed to its higher frictional force. However, the sample with 10%Mo and 10%B is harder and more wear-resistant than the steel. The mechanism for the improvements will be discussed. Mo and B additives have demonstrated their great promise to effectively modify Cu-Ni alloys.

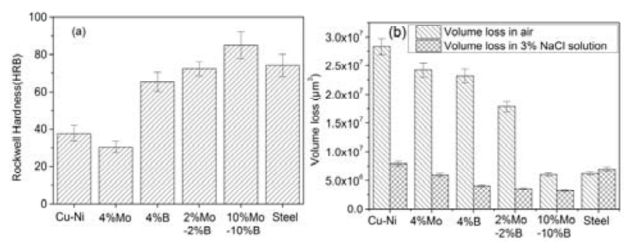

Figure 1 (a) Rockwell Hardness (b) Wear test volume loss in different environment

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