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Design and characterization of new Cu alloys to substitute Cu–25%Ni for coinage applications

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ABSTRACT

As the material and manufacturing cost of coins approached or even exceeded the face value of coins over the last 10 years, the needs to develop less-expensive alloys to replace the current coinage materials increased. The objective of this study is to develop new cost-effective alloys with the same vending machine acceptability and similar color tone as Cu–25%Ni coins. Cu–Zn–Ni–Fe and Cu–Zn–Ni–Fe–Cr alloys developed in this study were found to have the electrical conductivity close to and color similar to that of Cu–25Ni. The strengths of the annealed Cu–25.5%Zn–12%Ni–1.5%Fe and Cu–25.5%Zn–12%Ni–1.5%Fe–0.28%Cr alloys were observed to be 451 MPa and 512 MPa, respectively, with excellent ductility, suggesting that these alloys could be substitutive to Cu–25%Ni alloy for other general structural applications as well as coinage application. Both alloys exhibited the typical ductile fracture surfaces. Cu–Zn–Ni–Fe alloy was found to be a better candidate for coins because of the better formability and machinability associated with its moderate strength and excellent ductility.

1. Introduction

The currently circulating coins were mostly designed before 1982 [1–4] and the current material and manufacturing cost of some coins are close to or above the face value because of the sky-rocketing prices of some alloying elements over the last 10 years. Therefore, it is imperative to develop cheaper alloys for coins in many countries. There is only a fraction of coins with a low-face-value circulating because of ever-increasing price of commodities. It is therefore more economical to manufacture low-face-value coins with much less-expensive materials. A Cu–25 wt.%Ni alloy with good wear and corrosion resistance is rather expensive compared with other coinage materials and has been used to manufacture coins with relatively high face values. Cu–25 wt.%Ni alloy was frequently referred to as 'white copper' or 'German silver' because of its metallic whitish color and has been used as a substitute metal to replace silver coins [5].

In Korea, coins with face values of 100 won and 500 won have been manufactured with a Cu–25 wt.%Ni alloy. As of July 25, 2010, the exchange rate of Korean won against the US dollar went up around 1200 won/a dollar. Consequently, the face values of 100 won and 500 won coins increased to ~0.08 and ~0.42 US dollar, respectively. As the exchange rate increases, the metal prices converted in Korean won increases, rendering this project more attractive. Therefore, it is necessary to develop less-expensive new alloys in Korea like in many other countries. One problem which is expected from the introduction of new coins with newly developed alloys could be the rejection from the vending machines built to recognize the currently-used coins made of a Cu–25 wt.%Ni alloy. To avoid the entire replacement of currently-used vending machines and minimize the possible confusion from the public because of a sudden color change of the coins with the same face value, newly developed alloys are required to have the same vending machine acceptability and similar color tone as the currently-used alloy (Cu–25%Ni) coins. New alloys are also required to have good formability, excellent corrosion resistance and adequate mechanical strength. The objective of the present study is to develop and characterize new alloys that can substitute Cu–25 wt.%Ni alloy for coinage applications.

2. Experimental

Electrolytic copper, nickel, zinc, iron and chromium with a purity of 99.9% were used as starting materials. Cu–Zn–Ni–Fe and Cu–Zn–Ni–Fe–Cr alloys with various solute contents were cast by a vacuum arc and induction melting. For a preliminary study, small Cu–Zn–Ni–Fe and Cu–Zn–Ni–Fe–Cr alloy buttons with various compositions were made using vacuum arc melting in order to examine the effects on the electrical conductivity of iron and chromium in Cu–Zn–Ni base alloys. The list of the starting alloys cast by a vacuum arc melting and their compositions are summarized in Table 1. After the effects of iron and chromium on the conductivity were analyzed, 3 kg ingots of Cu–Zn–Ni–Fe

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