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Failure analysis of a lead-free brass tap used in potable water

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ABSTRACT

In this case study, the failure cause of a lead-free brass tap was investigated. The features of cracks were carefully studied by macroscopic inspection, chemical analysis, optical microscopy (OM), scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). The analysis results showed that the micro segregation of bismuth in the failed lead-free brass tap was considered as an important reason for crack formation. Further examination indicated that coarse bismuth rich phases were distributed mainly along grain boundaries. The cracks were found to be a typical intergranular failure, which revealed brittle fracture for the failed lead-free brass tap. It is expected that this work may help reduce the incidences of failures during the productive process of the lead-free brass taps.

1. Introduction

Copper alloys containing lead have been widely used for potable-water plumbing systems for a long time. Lead as a soft dispersoid in these alloys can improve castability and machinability. However, it is limited due to the new world regulations and to restrictions on potential leaching of lead to water. Therefore, new alloys without lead are being developed for plumbing purposes [1–5]. Bismuth (Bi) has been considered to be the best replacement for lead due to enhancing the machinability of copper as a nontoxic additive [6–8]. Unfortunately, extensive use of this lead-free brass with the bismuth additive may still face enormous challenges due to various failures.

In the present paper, a failed lead-free bismuth brass tap was investigated to find out its failure cause. The conclusions were obtained after carrying out macroscopic inspection, chemical analysis, metallographic examinations, scanning electron microscopy (SEM) observations and energy dispersive spectroscopy (EDS) analysis. The purpose of this study is to better understand the main reason of crack and avoid the loss of product and time due to the failure of lead-free brass taps.

2. Experimental procedure

2.1. Casting process

In the investigation, the cast lead-free brass taps are a kind of elbow pipe used in potable water. The casting process was made in a manual-operated equipment on a metal mold consisting of a sand core. Liquid metal was poured into the mold cavity during 5 s at 1080 °C with an inlet of 0.5 kg/s, and the solidification process took about 100 s. It was found that the percentage of the failure in production was about 10%.

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2.2. Analysis and test methods

In order to analyze the failure of the cast lead-free brass taps, a macroscopic inspection was performed to characterize the failure of the component. After that, microscopic examination of the failed lead-free brass tap specimens were subjected to conventional metallographic grinding using different grits of silicon carbide papers starting from 200 grit to 1000 grit. After a thorough wash, they were subjected to polishing using a finish polish. The freshly polished specimens were then chemically etched using a solution of HNO_3 (100 mL) + C_2H_5OH (100 mL) + H_2O (50 mL) for normal light microstructure observation. They were examined by an optical microscope (LEICA-DMI3000M), scanning electron microscopy (JSM-5610LV) and energy dispersive spectroscopy (EDS).

The microhardness of the failed lead-free brass tap specimen was measured using a microhardness analyzer at a load of 100 g. At least five points were tested under identical conditions to obtain an average.

3. Results

The failure zone of the lead-free brass tap was attentively investigated by macroscopic inspection, chemical analysis, optical microscopy and SEM/EDS, which revealed the physical appearance of the failure of the tap. The results of the investigation of the failed lead-free brass tap are presented in the following sub-chapters.

3.1. Macroscopic inspection

The cracked lead-free brass tap which was received for investigation was photographed using a digital camera. Fig. 1 shows the macroscopic morphology of the representative failed lead-free brass tap. It is clearly seen that the crack location was examined and found in the vicinity of the elliptical plughole zone. The outside surface of the polished lead-free brass tube was smooth. However, the severely curved crack was found to start from the elliptical plughole with about 1.5 mm wall thickness and propagated further toward the depth.

The failed tap was further cut to examine the characteristics of the crack edge. Low-magnification inspection of the crack surface was performed using a stereomicroscope, as shown in Fig. 2 (a and b). It is found that concave–convex shapes in the crack edges of the outside or inner surface are detected, and the feature of plastic deformation in the crack edge cannot be observed.

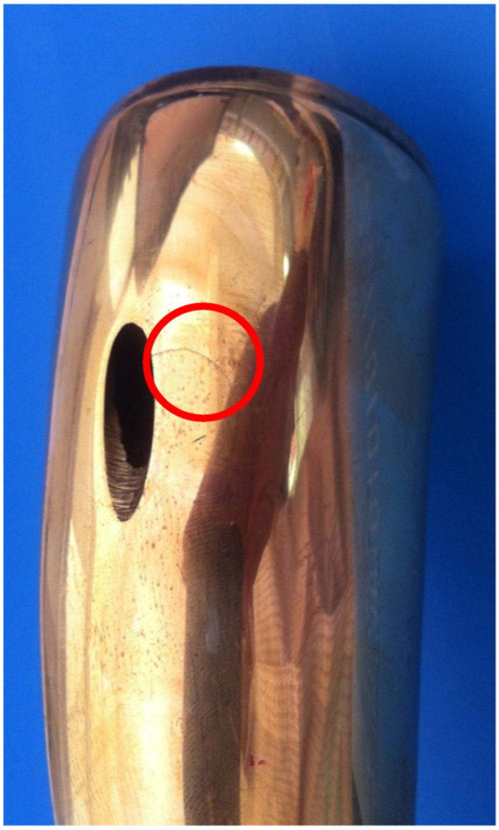

Fig. 1. The macroscopic morphology of a localized crack failure on the surface of the investigated lead-free brass tap (red circle shows the crack zone).