Engineering Failure Analysis 36 (2014) 314–321

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Surface degradation of nickel-plated brass fittings

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ARTICLE INFO

Article history:
Received 21 August 2013
Received in revised form 27 September 2013
Accepted 23 October 2013
Available online 1 November 2013

Keywords:
Brass
Oxidation
Corrosion
Nickel

ABSTRACT

Since many years, brass has been used in many engineering applications given its low production cost, fairly simple manufacture routes and acceptable corrosion resistance. Brass of many different chemical compositions can be found in complex engineering devices such as turbines and bearings or in ornamental and housing applications from which, the fabrication of fittings and connections for plumbing purposes are the most common. In this work, the surface degradation of nickel-plated brass fittings designed for ornamental plumbing purposes was studied using optical and scanning electron microscopy together with energy dispersive and X-ray diffraction analyses. It was found that this phenomenon was caused by the formation of zinc and copper oxides at the metal-coating interface and that reached the surface by means of growing through cracks that were also formed in the nickel coating. The occurrence of these defects is explained in terms of the cleanness of both, the brass specimens and the electrolytic solution used for plating.

1. Introduction

Brass can be considered as a common metallic system for the manufacture of components that are normally exposed to corrosion environments whether in engineering or decorative applications. In particular, brasses of different metallurgical grades have been used for the fabrication of pipes, connections and fittings for plumbing purposes therefore, their corrosion properties are well known [1–7].

Currently, the study of brass corrosion has gained considerable importance because this phenomenon plays an active role on the degradation and catastrophic failure of engineering components used in water distribution systems [8–11]. Regarding the corrosion of plumbing devices, this phenomenon has received especial attention given the severe detrimental effects that can exert on the life of living organisms. As an example of this, Zhang [8] and Kimbrough [9] mentioned that the corrosion of brass prepresents one of the most important sources for the incorporation of heavy metals into water systems for human consumption.

In this work, the causes that promote the formation of corrosion products on the surface of nickel-plated brass fittings for decorative plumbing applications is reviewed and discussed.

2. Experimental procedures

A company dedicated to the manufacture brass fittings and connections for plumbing revealed that their users experienced a severe problem after the installation of decorative pipes. Particularly, it was reported that nickel-plated brass fittings

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http://dx.doi.org/10.1016/j.engfailanal.2013.10.019

and connections experienced the formation of stains on the surface, which in principle, suggested the formation of oxides. This phenomenon was found in a considerable number of pieces made from two different chemical compositions (Table 1). In order to determine the source of this problem, samples were collected directly from users that encountered this problem in items already installed.

Regarding the manufacture route of these items, the final shape is given desired shape by means of cold forging. After this process and in order to improve surface quality and appearance, a nickel layer was applied to these elements by electrolytic means. The plating bath included the standard components namely nickel chloride $NiCl_2$, nickel sulphate $NiSO_4$ and boric acid H_3BO_3 diluted in deionised water to give a pH comprised between of 4.6 and 5.3. The exact chemical composition used during the process cannot be provided given that this variable is confidential however, the nickel plating procedure can be best described elsewhere [11–14].

Given that no information was known on the microstructure of the alloys, this was determined by conventional metallographic techniques which included grinding the samples with various grades of SiC papers and final polishing stages with diamond pastes of 6, 1 and ¼ μm respectively. After this stage, the specimens were etched using a solution of 2 g ferric chloride ($FeCl_3$), 10 ml hydrochloric acid (HCl) and 50 ml methanol (CH_3OH). Alternatively, the surface of damaged and undamaged specimens was studied using light optical microscopy. X-ray diffraction analyses were also performed on damaged and undamaged samples using a diffractometer coupled with a Cu Kα lamp producing radiation at 40 kV and 30 mA. Scans were collected at rate of 0.020°/min over a 2θ range comprised from 20° to 100°.

The surface morphology of the nickel-coated brass specimens that presented severe stain formation was also analysed using scanning electron microscopy. Prior to the analysis, the samples were coated with a thin layer of sputtered gold to allow charge dissipation during inspection. Energy dispersive X-ray analyses (EDX) were taken from specific zones aiming to identify the elements present in the stains. After surface inspection, cross sections of the samples were also prepared for examination in the SEM following the metallographic procedures described earlier. This procedure allowed identifying if the stains originated from the nickel coating or from the base material.

Table 1
Chemical composition of the alloys.

Alloy	Alloying elements wt%			
	Cu	Zn	Fe	Sn
A-70-30	69	29	1.1	0.80
B-60-40	60	38	1.2	0.81

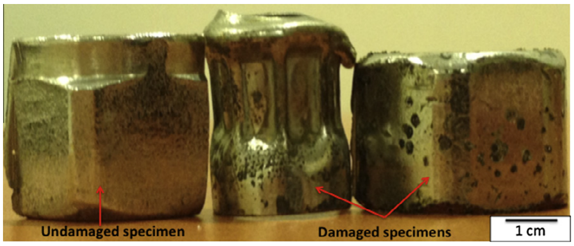

Fig. 1. Photographs of the nickel-plated brass fittings. (a) With stain formation. (b) No stain formation.

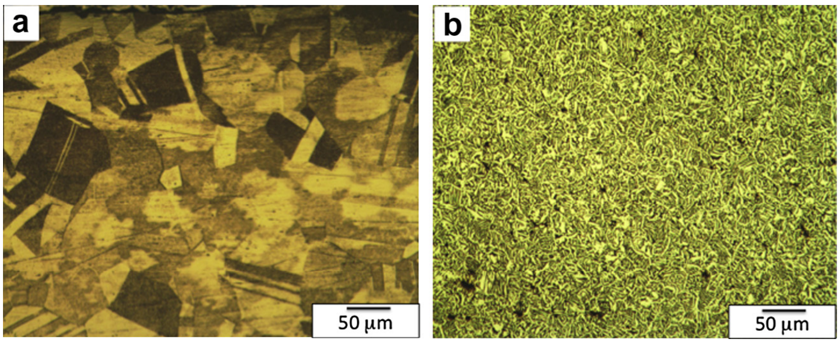

Fig. 2. Light optical microscopy images of the microstructure of the alloys. (a) Annealed brass. (b) Widmastatten brass.