CRACKING OF BRASS FITTINGS IN WATER DISTRIBUTION SYSTEMS

R. Pascual[1)], C Bagnall[2)], I Le May[1)]
[1)]Metallurgical Consulting Services Ltd, 3611 48 Ave., S.E., Calgary, AB, T2B 3N8, Canada
[2)]MCS Associates, Inc., 637 Donohoe Road, Latrobe, PA 15650, USA

ABSTRACT

Brass fittings from domestic water distribution systems that failed prematurely have been examined using metallographic and fractographic procedures. It is concluded that, although the fittings met the relevant standards for composition, they failed by stress corrosion mechanisms. It is suggested that that, if such alloys are to be used in similar applications in the future, there is a need for improved and stricter compositional standards, or, alternatively, that non-metallic fasteners may need to be substituted.

KEYWORDS

Brass fittings, domestic water distribution, stress corrosion, fractography, PEX tubing

INTRODUCTION

PEX (cross-linked polyethylene) tubing was developed in the 1960s and is widely used in residential water plumbing because of flexibility and ease of installation. PEX tubing has long been used European countries and was introduced in the USA in the 1980s. It is manufactured and tested according to several standards [1-6] and is an approved material in most current plumbing codes. Most PEX installations are made using brass fittings that comply with current standards [4]. Even if the PEX tubing has proved to be reliable a substantial number of failures of the brass fittings have occurred, in many cases after brief use. This has led to a many claims, two of which will be analyzed to show installations made in accord with standards can lead to component failure and consequential damage..

BRASS FITTING FAILURES

Example 1

Fig. 1 shows a failed elbow that had been attached with copper crimps to 12.5 mm PEX tubing in a domestic installation. Fig. 2 shows the elbow side in which oxide has formed close to where fracture occurred, while Figs 3 and 4 show the two sides of the fracture surface.

Fig. 1: The two parts of the failed fitting

Fig. 2: View of the elbow side of the failed fitting

Fig. 3: : One of the fractured fitting pieces attached to the PEX pipe

Fig. 4: Fracture surface on the elbow side

The piece of elbow shown in Fig. 3 was sectioned longitudinally. The results are seen in Figs 5 and 6. Dezincification can be seen on the cross section surface in Fig. 5. In many regions, dezincification was observed to extend perpendicularly to the surface as shown in Fig. 6.

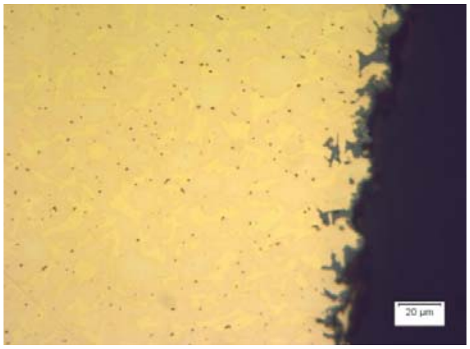


Fig. 5: 500x. Dezincification at the internal surface

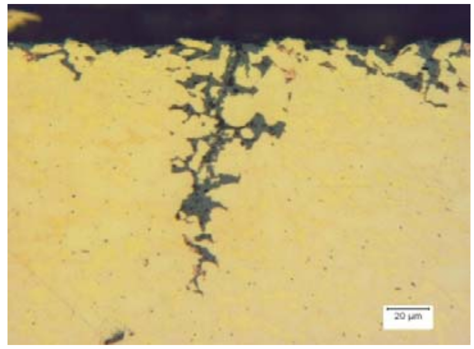


Fig. 6. 500x. Dezincification extending in the interior

SEM observation of the cross section was also made. Fig. 7 shows a typical observation. Dezincification can be also seen on the surface of the sample.

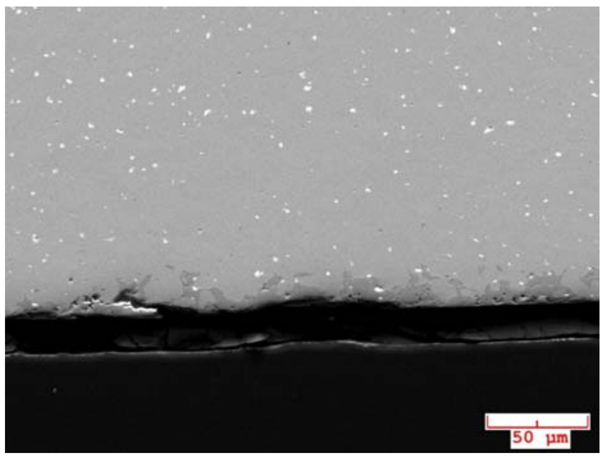


Fig. 7: 2000x. SEM view of dezincification on the internal surface

Optical and SEM observations show features typical of dezincification, and this is shown conclusively from scanning the Zn peak along the line shown in Fig. 8, which traverses the dezincified region. It can be seen that the intensity of the Zn peak intensity is reduced strongly in the region.

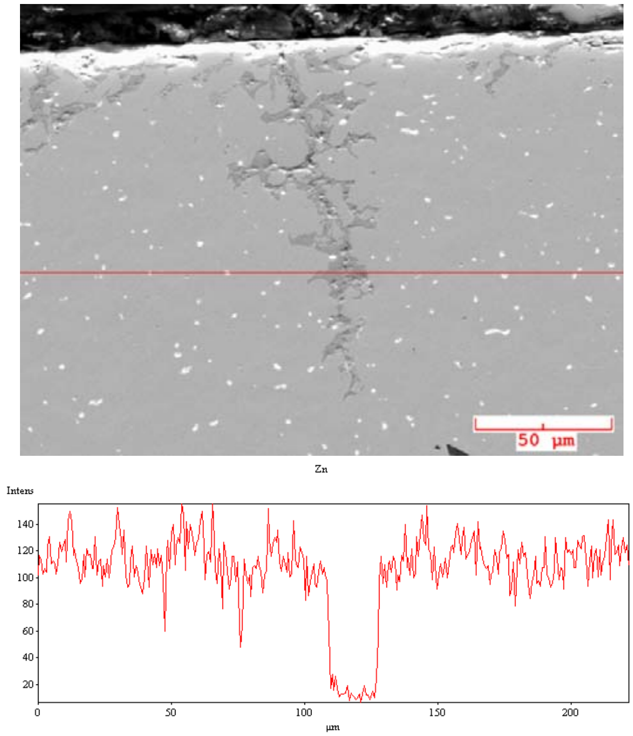


Fig. 8: 1500x. Zinc peak intensity scan along the red line.

Conditions generally present when dezincification occurs include: water with high levels of oxygen and CO_2; low pH water combined with oxygen that forms zinc oxide; water with high Cl^- content; or neutral or alkaline waters high in salt. It is usually recognized by the presence of a white deposit of zinc oxide, as here. When dezincification occurs, depletion in zinc is observed, leaving the affected region mechanically weak. In this case, dezincification started at several places on the internal surface. Penetration reduced the thickness of the fitting until fracture took place. Dezincification may occur locally because of internal stress generated during machining..

Brass with high zinc content is more likely to be affected. Fittings to be used with PEX tubing have to comply (in Canada) with specifications established in the relevant CSA standard [4]. Chemical analysis indicated that the material conformed to this. The choice of fittings with higher copper content is recommended when aggressive environmental conditions are present. This will still comply with specifications in the relevant standard but would reduce the possibility of dezincification. Alternatively a dezincification-resistant brass, usually with the addition of arsenic, could be used.

Example 2

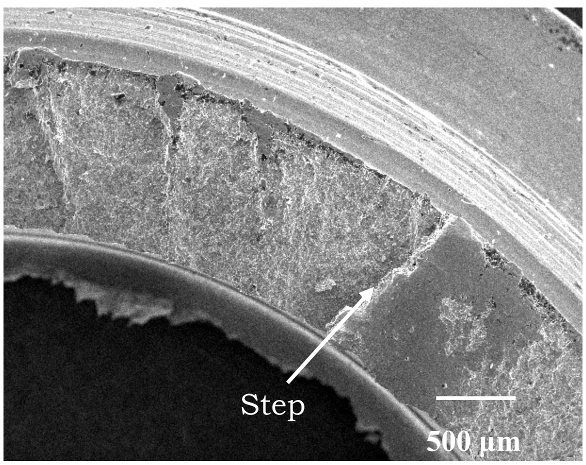
The second example is also from a domestic installation and involves a fitting from a hot tub water line that was less than one year old when it broke. The fitting connected two 12.5 mm PEX pipes using copper crimp rings and fractured inside the blue pipe shown in Fig. 9.

Fig. 9: The two pieces of the failed fitting.

Fig. 10: Fracture surface of the failed fitting

One side of the fracture surface is seen in Fig. 10, and radial steps are seen on the surface. Examination showed that the steps all ran in the same direction suggesting the section had been subjected to torsion.

Fig. 11 shows a low magnification view of the fracture surface, with a step indicated by the arrow. The top surface of the step is flat indicating rubbing with the other fracture surface.



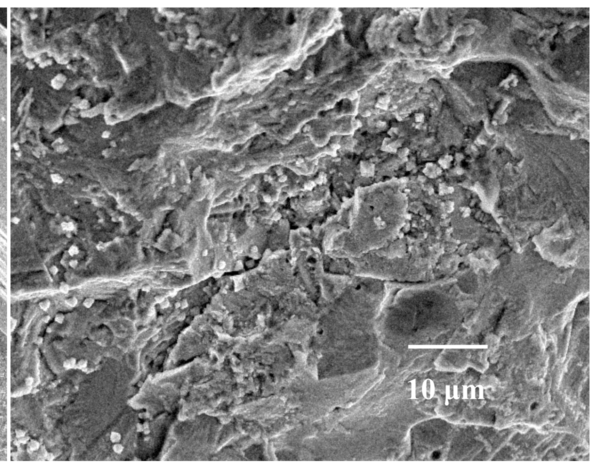
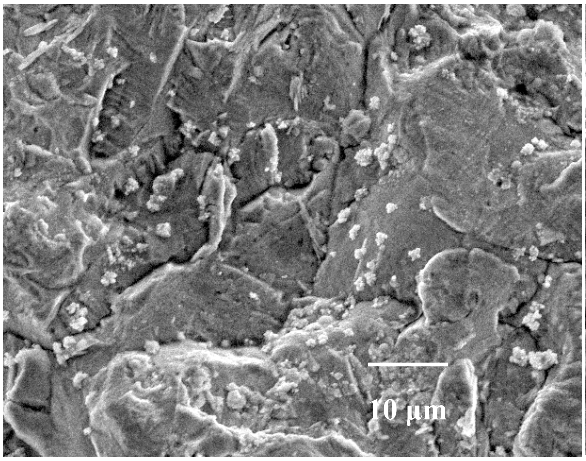


Fig. 11: 35x. General view of the fracture surface.

Fig. 12: 2000x. Inner edge: oxidation and intergranular fracture.

A higher magnification view at the inner edge of the fracture surface (Fig. 12) revealed the presence of corrosion products as well as a crack running diagonally across the picture: regions of intergranular cracking are observed. Fig. 13 provides another example of intergranular cracking and brittle fracture in the center of the fracture surface. A view of the outer region of the fracture surface can be seen in Fig. 14. Ductile fracture is prevalent in this region. A crack is seen in the region further from the edge.



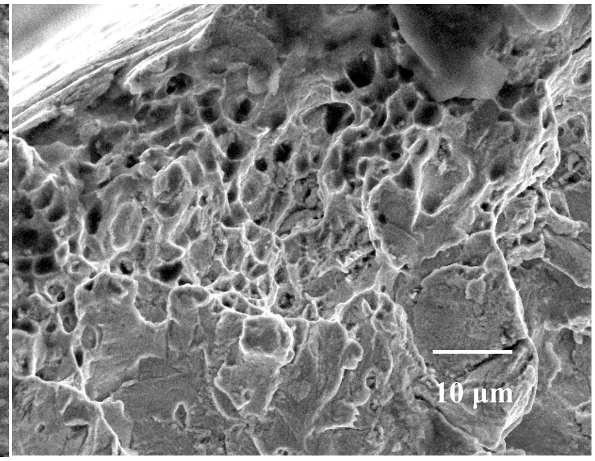


Fig. 13: 2000x. Center region. Intergranular fracture.

Fig.14: 1500x. Ductile fracture on the outer edge.

Fig. 15 shows a region of the inner edge of the fracture surface. The sample has been tilted in order to observe the inner surface of the fitting. Rough machining markings can be seen running both longitudinally and parallel to the fracture surface.

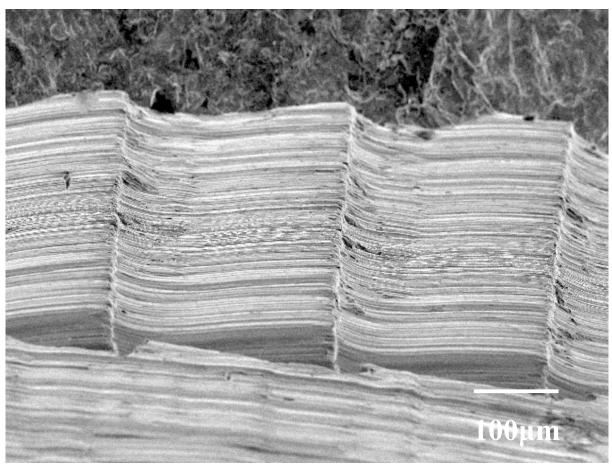


Fig. 15: 200x. Machining marks on inner surface.

Observations of the longitudinal cross section were made using optical and as well as scanning electron microscopy. Fig. 16 shows a crack starting at the internal surface of the fitting and extending perpendicularly to the wall into the interior, branching being observed, a higher magnification view of this being given in Fig. 17.

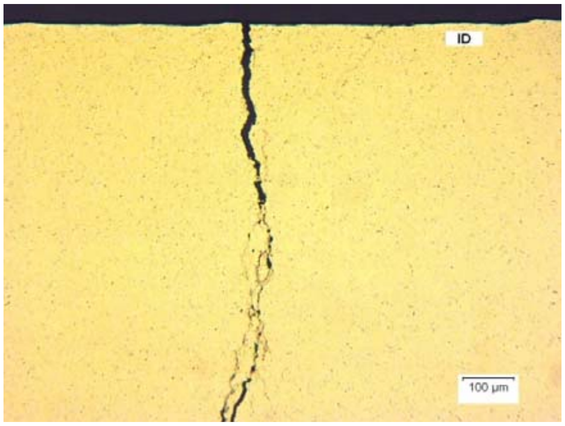


Fig. 16: 100x. Crack starting at the internal surface.

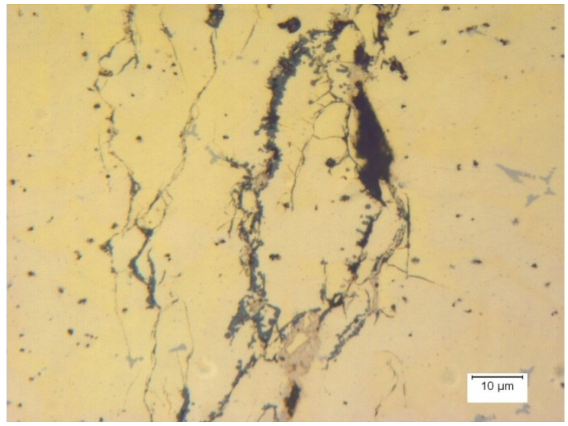


Fig. 17: 1000x. Details of branched crack.

Rough machining markings were observed in the interior wall - see Figs 18 and 19.

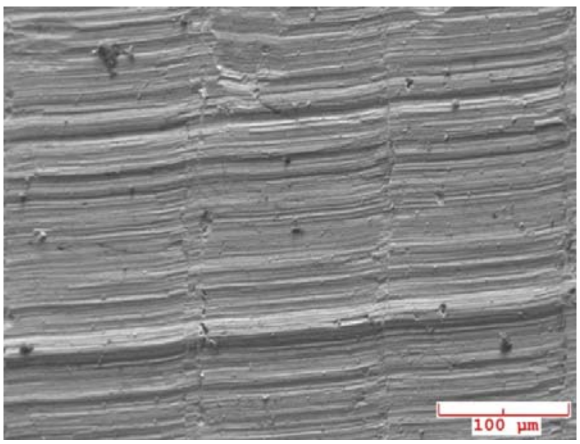


Fig. 18: 500x. Machining markings on inside surface.

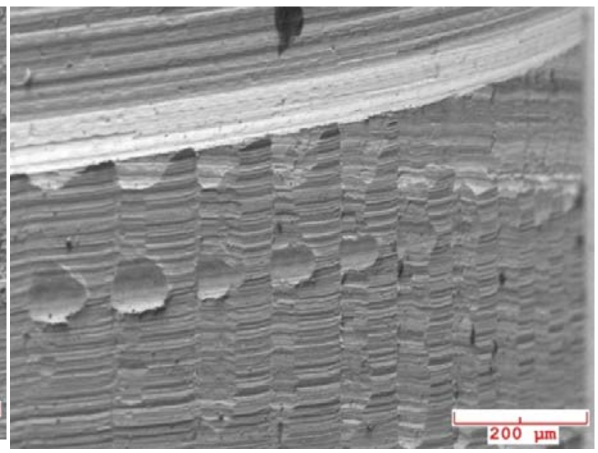


Fig. 19: 250x. Machining markings on inside surface.

The examinations of the failed fitting show that the fracture process started at the inner wall surface and extended to the interior. The characteristics of the fracture surface near the inner surface and of the cracks observed branching towards the interior of the sample indicate that the mode of fracture was stress-corrosion cracking.

Brasses are known to have, under certain conditions, high susceptibility to stress corrosion in sufficiently aggressive environments. The composition of the water used in this case is not known. However, in many cases water from wells or even from municipal supply can have high contents of salts that can eventually induce stress corrosion if the level of stress in the component is sufficiently high.

In the brass fitting under analysis, rough machining markings were observed (see Figs 15, 18 and 19). These can generate high residual stresses in the material which can produce the conditions for stress corrosion cracking. These stresses could be reduced substantially by modifying the machining process or by increasing the wall thickness of the fittings.

Even if the cracks have started by a stress corrosion cracking mechanism, final failure seems to have taken place by ductile fracture due to stress overload. The stress acting on the fitting at failure does not seem to be normal to the fracture surface but appears to have had a strong torsional component. This raises the possibility that an external force has been applied torsionally to the fitting at the moment of failure. Without that, the fitting could have lasted for a longer period but would eventually have failed.

CONCLUSIONS

1. The brass fittings used for connection of PEX tubing that failed met the relevant standards for composition, but both failed by a stress corrosion mechanism.

2. To prevent or minimize such failures in future, the current standards for composition of may require modification and stricter control.

3. Alternatively, the use of non-metallic fittings for the connection of PEX tubing for water supply connections may need to be developed.

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Corresponding author: lemayi@metallurgicalconsulting.net