Engineering Failure Analysis 90 (2018) 197–201

Contents lists available at ScienceDirect

Engineering Failure Analysis

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

Short communication

Stress corrosion cracking of a copper elbow fitting

R.G. Metcalfe[a,*], N. Pearce-Boltec[b]

[a] Engineering & Materials Science Group, Bureau Veritas–Asset Integrity & Reliability Services, 29 Rosegum Close, Warabrook 2304, NSW, Australia
[b] VIC/TAS BOC Limited, 13A Albert Street, Preston, Victoria, Australia

ARTICLE INFO

Keywords:
Amines
DHP copper
Elbow fitting
Intergranular SCC
Liquid nitrogen pipeline
Polyurethane insulation

ABSTRACT

This paper presents the results of an examination of cracking in a phosphorous deoxidised copper fitting that had been installed in a liquid nitrogen line. The service life of the fitting was reported to be three to four years.

Failure was a result of the Stress Corrosion Cracking (SCC) from the outside surface that had been placed in tension by the pipeline being chocked with a block of wood to locally raise the line above a cable tray. The active species for SCC was suspected of being Amines in the Polyurethane insulation.

1. Background

A 45° copper elbow fitting of approximately 1″ OD from a liquid nitrogen line was examined following the detection of a crack. Two (2) previous fittings had also cracked, although details from these failures were not available. This most recent failure was on the underside of the downstream end of the fitting on a pipeline that had been raised above a cable tray at a position further downstream, by chocking the line up with a block of wood, in order to raise it about 100 mm over a few metres.

The fitting was part of a pipeline that cycled between liquid nitrogen and ambient temperature for an 8 hour shift once every day as part of a batch freezing process. The pipeline was surrounded by polyurethane foam and contained within a PVC shell of approximately 6″ ID. The fitting was a standard domestic copper component rather than the R410A refrigerant grade fittings typically used in commercial operations, which are of greater wall thickness.

The service life to failure of the fitting was reported to have been approximately 3 to 4 years.

2. Visual examination

A general view of the fitting is presented in Fig. 1. A circumferential crack approximately 25 mm long was present at the bottom surface of the downstream end, see Figs. 1 and 2. Evidence of a black oxide was present on the surface. The upstream end of the fitting was crack free.

A longitudinal section was taken through the fitting in order to examine the bore directly below the surface crack. The crack was found to have extended through the wall of the fitting resulting in an approximately 12 mm long circumferential crack in the bore.

Longitudinal cuts were made intersecting the extremities of the crack in the outer surface in order to open the crack and expose the crack face. The crack had propagated normal to the surface through the approximately 1.2 mm thick wall.

The crack face exhibited a dark, discoloured region at the outer surface extending to a depth of approximately 0.9 mm before exhibiting a bright copper coloured surface, see Fig. 3.

* Corresponding author.
E-mail address: roger.metcalfe@au.bureauveritas.com (R.G. Metcalfe).

https://doi.org/10.1016/j.engfailanal.2018.03.016
Received 5 September 2017; Accepted 13 March 2018
Available online 14 March 2018

Fig. 1. General view of cracked fitting.

Fig. 2. Magnified view of crack in the external surface of the fitting.

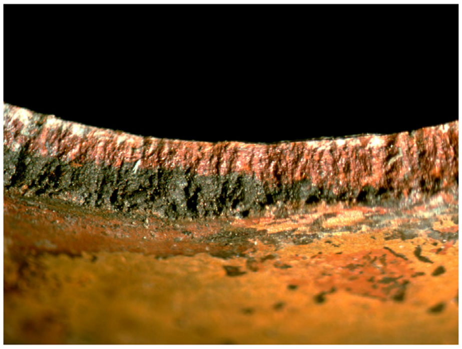

Fig. 3. Magnified view of crack surface.

An examination of the fracture face was performed using an Hitachi TM1000 Scanning Electron Microscope (SEM). Examination of the mid wall region indicated the presence of crack arrest marks on the surface, that have been associated with transgranular cracking [1], and a decrease in secondary cracking, see Fig. 4.

3. Microstructural examination

A longitudinal section was subsequently taken though the fitting intersecting the mid crack position, and the sample prepared using standard metallographic techniques. A number of branching cracks consistent with Stress Corrosion Cracking (SCC) were present in the outer surface of the fitting of gradually decreasing depth on moving away from the fracture face, see Fig. 5. These cracks appeared to contain an oxide similar to that found on the fracture face and to be intergranular. The main fracture surface showed an intergranular path for the first one third of its length before following a transgranular path to the bore.

The sample was etched and indicated an equiaxed microstructure consistent with the annealed condition with cracking appearing to follow a largely intergranular path, see Fig. 6. Hardness testing indicated a hardness of approximately 63HV1.

An SEM examination using back scattered electrons (BSE) was performed in order to highlight the presence of oxide at the grain boundaries, see Fig. 7.