M. E. Williams and Associates, Inc.

"Excellence in Metallurgical Engineering"

12825 385th Avenue
Waseca, MN 56093

Case Study: Leak in Inner Groove Tubing

By

Merlin E. Williams, P.E.

Subject

Modern cooling and refrigeration systems use Polyester Oils, POE oils, as lubricants. The problem with POE oils is that they decompose in the presence of water to form an alcohol and an organic acid. This was an examination of inner groove tubing to determine the cause of leakage in the hairpins. The hairpin was examined by visual examination, scanning electron microscopic examination, and metallographic examination.

Visual Examination

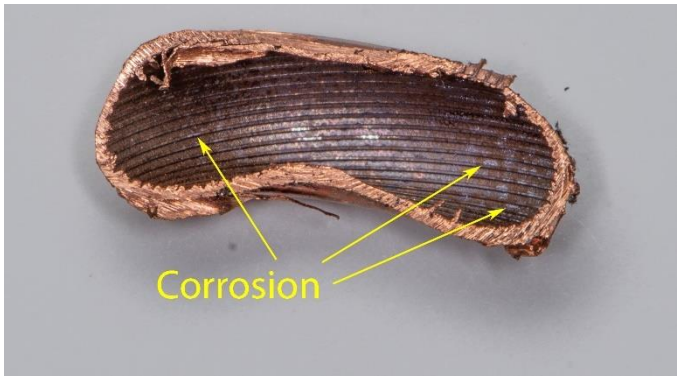

Figure 1 – Corrosion on the Inside of Hairpin

Figure 2 – Leak Indications on Outside of Hairpin

Figure 1 shows a section sliced from a leaking hairpin. There were purple colored deposits, indicated by arrows, on the inside of the tube, which are characteristic of corrosion products formed by breakdown of a POE oil.

Figure 2 shows the outside of the hairpin. The black marking indicates where leaking was found.

Scanning Electron Microscopic Examination

Figure 3 shows corrosion on the inside diameter of the hairpin. The crystallin deposits are typical of copper oxide crystals formed by corrosion in the presence of an acid and water. The EDS spectrum of this location, Figure 4, shows the presence of carbon, oxygen, fluorine, copper, and aluminum. The presence of fluorine indicates that municipal water was trapped at this location. Fluorides are not corrosive because of their very low solubility. The EDS analysis did not indicate the nature of the corrosive agent. This fact

indicates that the corrosive agent may have been an organic acid. The source of the aluminum detected was likely stray x-rays from the aluminum carrier the tube sample was on.

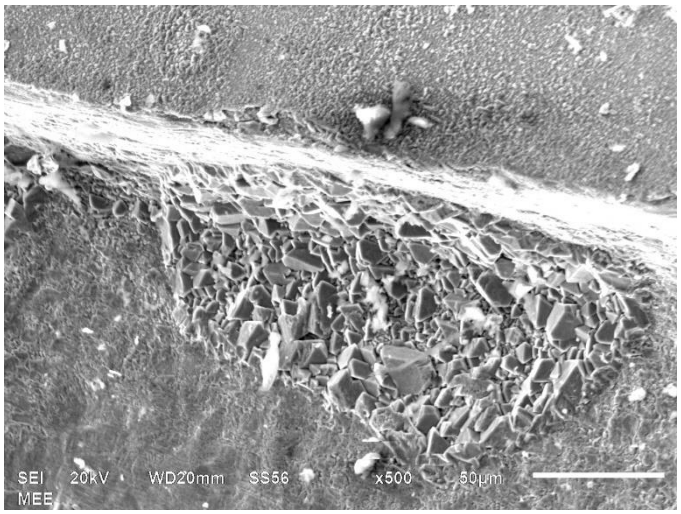

Figure 3 – 500X Corrosion on ID of Hairpin

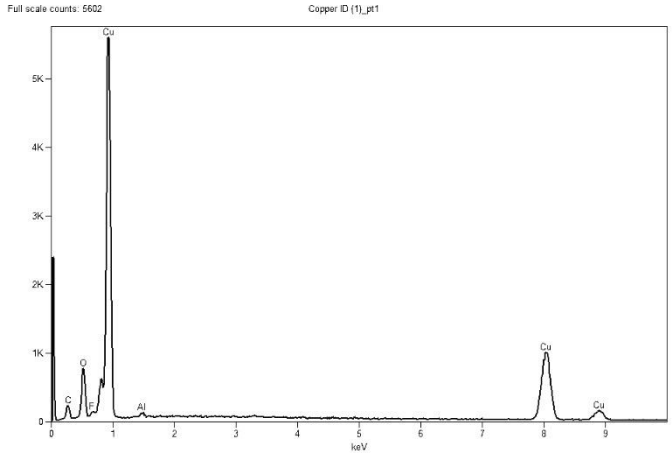

Figure 4 – Spectrum of Corrosion on ID of Hairpin

Forming of hairpins usually results in microscopic surface cracking. Figure 5 shows that condition in the tubing. The amount of surface cracking appears to be somewhat more than normal, but the condition could be the result of the drawing of the tubing at the mill, and did not appear to have been a contributing factor to the leaks in the hairpin.

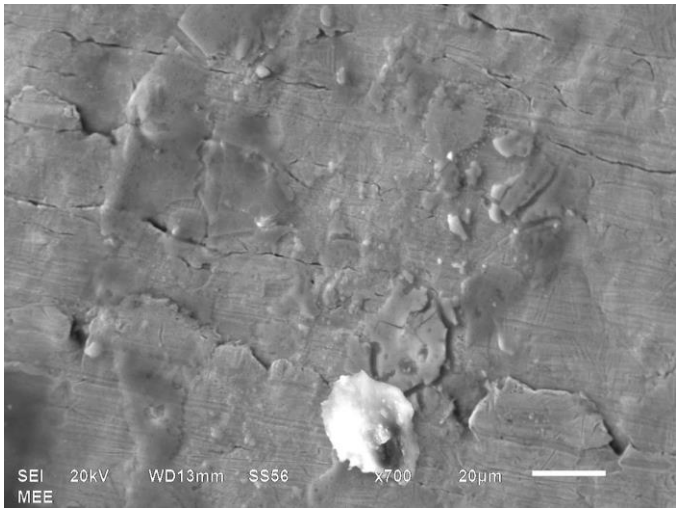

Figure 5 – 700X Surface Cracks on OD of Hairin

Metallographic Examination

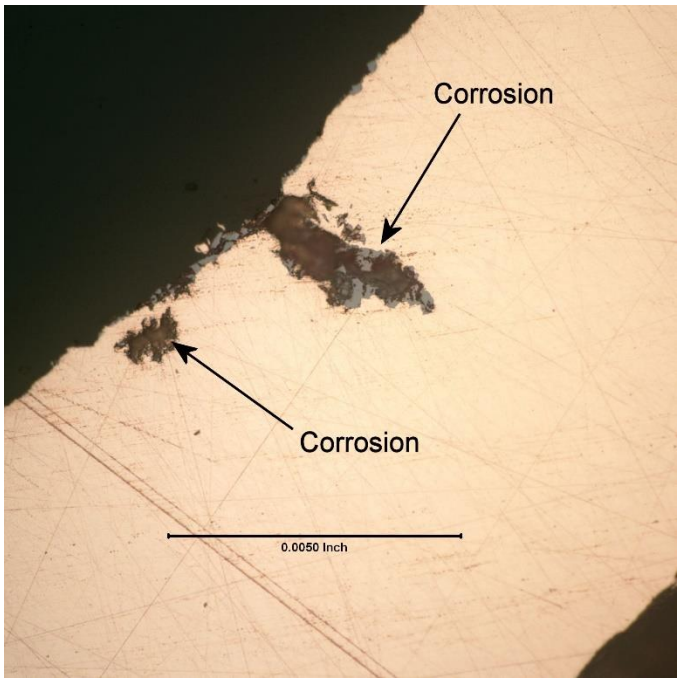

Figure 6 – 400X Corrosion on ID of Hairpin

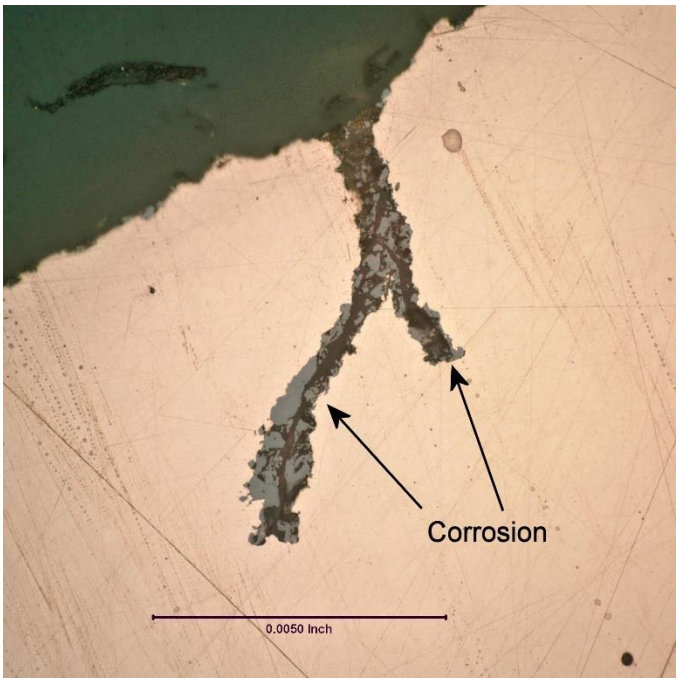

Figure 7 – 400X Corrosion on ID of Hairpin

Figures 6 and 7 show corrosion originating on the inside diameter of the hairpin. The corrosion has the visual characteristics of corrosion that resulted from the presence of water and POE oil. The corrosion pattern shown in Figure 7 has many of the characteristics of formicary corrosion.

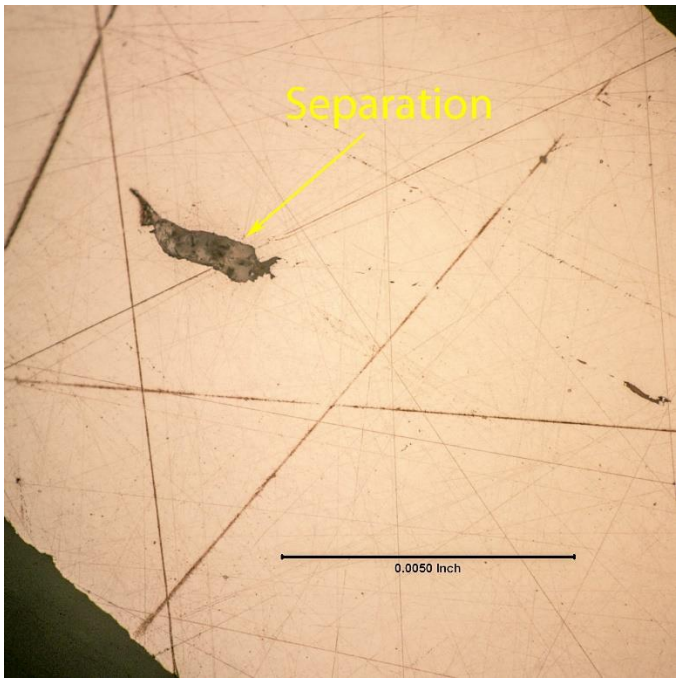

Figure 8 – 400X Separation in Tubing

Figure 8 shows a separation in the copper tubing. The separation was caused by incomplete bonding of the copper during the initial drawing of the tubing. There were no cases found where separations were connected with the corrosion in the inside diameter of the tubing.

Conclusion

The cause of leakage at the hairpin in the tubing was likely the breakdown of a POE oil in water on the inside diameter of the tubing. The presence of water was indicated by the fluorine associated with the corrosion products, Figures 3 and 4. The coloration of the inside of the hairpin is similar to the coloration found when POE oils are present. The corrosion patterns in the metallographic cross sections are similar to formicary corrosion found in copper tubing when POE oils and water are involved.