FORMATION AND ANALYSIS OF FINES

Fines are always generated during wire drawing as a very undesirable contaminant. They are a finely divided mixture of the metal conductor, its oxides, soaps, sludge, and other debris, and can cause such problems as die wear, surface damage, wire breaks, and deterioration of the drawing lubricant. Although fines occur for all ferrous and non-ferrous metals and alloys, this article deals specifically with copper conductors. Rod quality plays an important role, inasmuch as sub-surface oxides may facilitate an outer layer of copper to flake off during drawing. Consequently, the surface oxide thickness measurement, which typically incorporates a measure of subsurface oxides present, is directly proportional to the amount of fines that are generated downstream. In addition to copper and its oxides, fines may include organic or inorganic compounds that originate during wire drawing, rod pickling, and rod shaving. They are caused either by reactions of copper with the shaving or wire drawing lubricant, or between the copper rod and carryover of the sulfuric acid pickle solution. The majority of fines liberated from the wire are the result of five possible wear mechanisms that are summarized in the next paragraph.

Abrasive Wear occurs when asperities on the surface of the harder sliding contact, such as the draw die, remove particulates from the softer metal wire. Typical abrasive wear particles may be seen in *Figure 1*, and they are hard from cold work. Striation marks are usually visible on the surface of the drawn wire. In the case of polycrystalline diamond or carbide dies, abrasive wear is accelerated when fine grained dies are used. Additional hard particles such as fines, oxides, or slivers oftentimes settle between the draw die and the wire being drawn. This undesirable process is known as **Third Body Wear**, and can be more deleterious than plain abrasive wear because a greater number of sharp wear points are exposed. In this case the abrasive particles cause most of the wear on the wire. **Adhesive Wear** is likely when two solid bodies make sliding contact with each other. During this process the asperities undergo microscopic adhesion to each other and shearing, thereby resulting in the formation of wear particles. If lubrication is out of control, galling can take place when the softer wire bonds to the harder draw die. Adhesive wear may also occur when the wire makes contact with a capstan or an adjacent moving wire. A micrograph showing adhesive wear on a copper wear surface is shown in *Figure 2*. **Delamination Wear** nucleates as small cracks barely beneath the outer wire surface because of high internal tensile stresses that are generated close to the surface during wire drawing. These cracks propagate parallel to the wire surface and can be exacerbated when the wire is in the hard condition or if it is bent around a very small diameter. *Figure 3* shows a crack line in a copper wire that was created by delamination wear. Resulting wear fines oftentimes are thick, and exhibit the same curvature as the wire, as may be seen in *Figure 4*. The final wear

Approximately X 500

Figure 1 – typical fines that are produced by abrasive wear

Approximately X 50

Figure 2 – adhesive wear between two copper wires making contact with each other during drawing

mechanism is known as **Surface Deformation Wear**. Since the outer surface of the wire undergoes greater work hardening than its interior, it may become brittle and fracture, thereby forming small particles of fines. Seven different parameters can accelerate or aggravate the formation of fines. As might be expected, it is extremely important to have proper lubrication applied to each die, which includes complying with the recommended operating temperature and chemical make-up. High drawing temperatures tend to increase fines generation. Equally important is ensuring effective removal of fines by filtration since they can clog spray nozzles and die entrances, thereby causing third body wear and lowering surface quality and drawability. The need to have the best die geometry (especially blending), is imperative since hard wear surfaces such as grain boundaries surrounding the individual polycrystalline grains, wear rings, grain pull-out, broken nibs, and missing stone are all likely to contribute to the formation of fines by abrasive wear. Dies with numerous recuts often become too shallow at the entrance and create additional sharp surfaces. Residual stresses in the wire can cause excessive misalignment with the die, and drawing may commence outside the reduction zone. Severely misaligned dies at the die entrance or exit can create abrasive wear. Additional practices that can be used to reduce the formation of fines include increasing back-tension, removing fines from the wire surface, and using an idler roll before the draw die to reduce vibrations, which can disturb the hydrodynamic lubricant film and generate high die pressures.

Different techniques can be used for examining and analyzing fines, such as direct examination of the wire and rod surfaces to look for pits, galling, slivers, or protrusions. Another useful method is to examine fines that are collected from the wire drawing machine or filtration system because their shape and constitution can help to establish the operating wear mechanism(s). Monitoring the rate of fines generation on a regular basis can also prove beneficial. If rod surfaces are examined after twist testing, it may be possible to detect subsurface damage. Finally, the entire wire drawing process should be examined carefully to gain insights on fines generation.

By H.P.

Approximately X 50

Figure 3 – transverse wire section showing subsurface tensile cracks leading to subsequent delamination wear fines

Approximately X 500

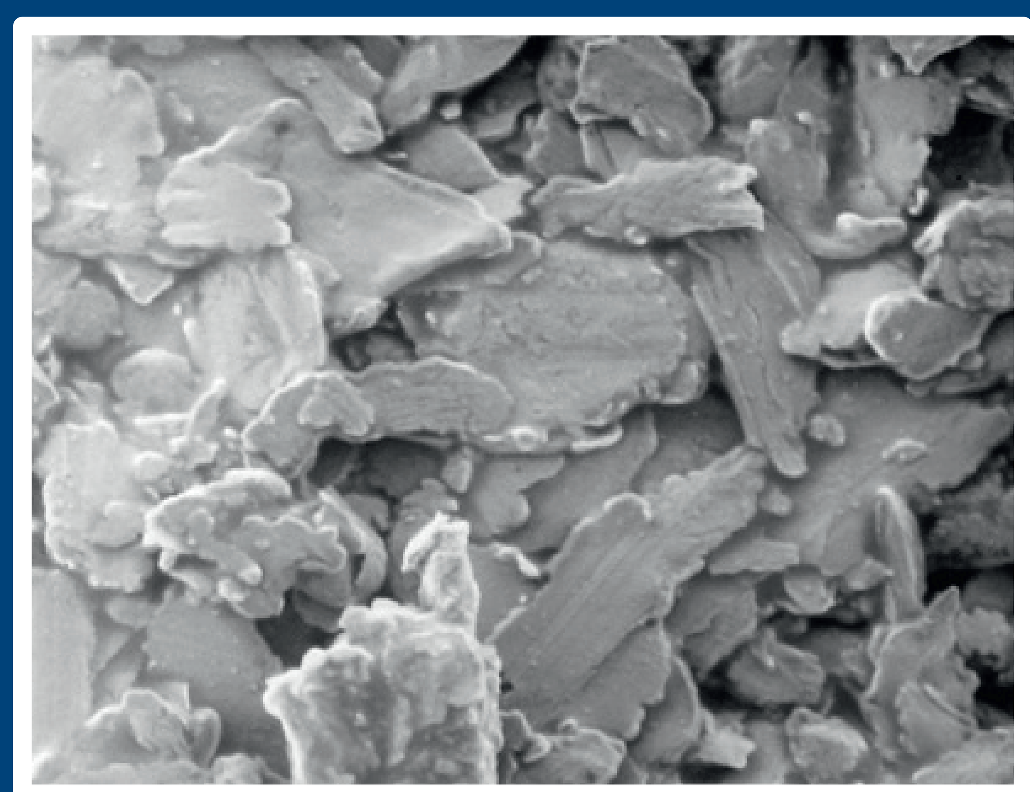

Figure 4 – fines resulting from delamination wear