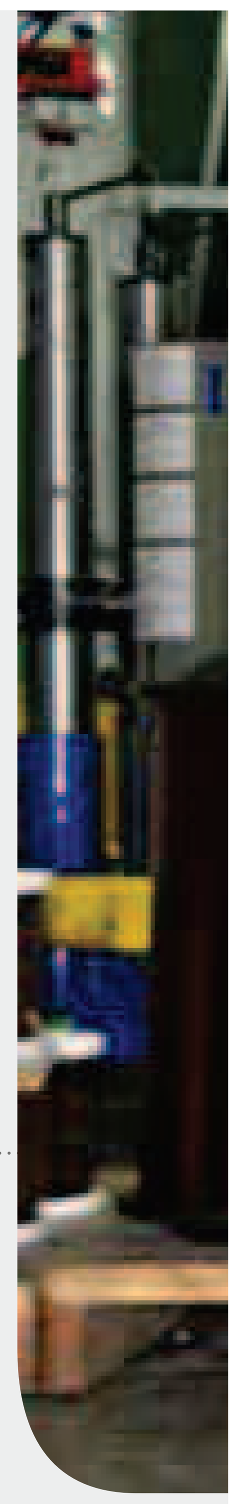
HIGH SPEED MULTIWIRE DRAWING MACHINES AND THE SEVERE REQUIREMENTS FOR COPPER ROD



Production of wire or cable involving multiwire technology has become very prevalent and includes rod breakdown, wire drawing, annealing, bunching or stranding, and packaging. Most of these drawing machines involve tandem wire drawing of two or more individual wires and give much better performance compared with step-cone machines. Some advantages of multiwire drawing machines over cone-type single drawing machines are less surface damage, lower fines generation, easier string-up, better alignment and guidance, more consistent values for annealed wires, higher cost savings, and reduced total manning of machinery. In contrast, however, in order to obtain many of these benefits downtime must be minimized, which requires a substantial reduction or elimination of wire breaks. Since a break of only one wire can wipe out numerous adjacent wires, the required subsequent string-up can take many hours of lost production or even an entire shift. Consequently, the control, monitoring, and quality of drawing dies, wire drawing lubricants, filtration systems, and cooling water are critical. Equally important is the fact that only the highest quality of premium grade rod should be used for multiwire drawing. Poor performance will result if the rod has inadequate surface quality, excessive generation of fines, and any internal or surface related defect. Although there are many process related variables during multiwire drawing, the present article deals only with those factors that lead to poor copper rod quality and causes subsequent wire breaks. Three primary processing variables discussed herein for all copper types are as follows:

Chemical Composition: the first step in producing high quality rod is to ensure that proper chemistry, including metallic impurities and oxygen content, is being achieved. ASTM and European ISO standards list the maximum allowed values of more than a dozen different elements for OF, ETP, and FRHC types of copper. Deleterious effects often occur for high levels of Bi, Se, Te, H, S, and Pb, even when they are within or close to their maximum allowed range. Cavitation fracture might take place if the lead content is between 10 and 150 ppm. This defect is a brittle type of high temperature intergranular fracture that occurs by the formation and growth of cavities (voids) at the copper matrix grain boundaries. Lowest ductility occurs at 400 °C, which is the bar temperature somewhere in the hot-rolling finishing mill. Hydrogen embrittlement in the cast bar may occur during continuous casting if the oxygen content in the molten copper is insufficient, i.e., not much greater than 100 ppm. In contrast, the likelihood of exacerbating brittle wire breaks increases at higher oxygen contents (>500 ppm) due to the formation of excessive amounts of oxides based upon copper and impurity metals.

Molten Metal and Solidification: rod related wire breaks frequently occur because of incorrect melting and casting procedures. For example, surface porosity often occurs on the cast bar by non-uniform heat extraction in the casting wheel, moisture in the mold release agent, or improper application of this material on the casting wheel. In the time period between solidification and hot rolling, these surface bubbles become oxidized, and although they close during rolling, the resultant sub surface oxides (SSO's) cannot be removed during pickling, and therefore may cause subsequent brittle wire breaks. During casting solidified copper splatters or drippings, referred to as icicles, sometimes fall into the casting wheel along with undesirable slag particles that get carried over from the tundish. These contaminants are also likely to cause brittle wire breaks. Macroporosity is a very common type of internal void that usually forms at the center of the cast bar during solidification. If the voids are large enough they do not close completely dur-

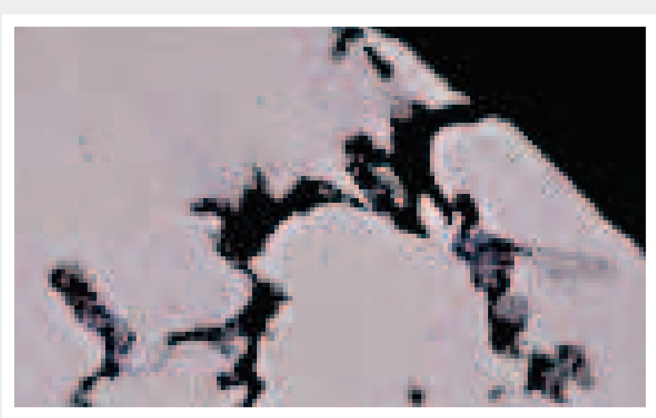


Figure 1 - Hot cracks that formed inthe copper matrix grain boundaries of the as cast bar due to excessive tensile stresses, thereby resulting in subsurface oxides

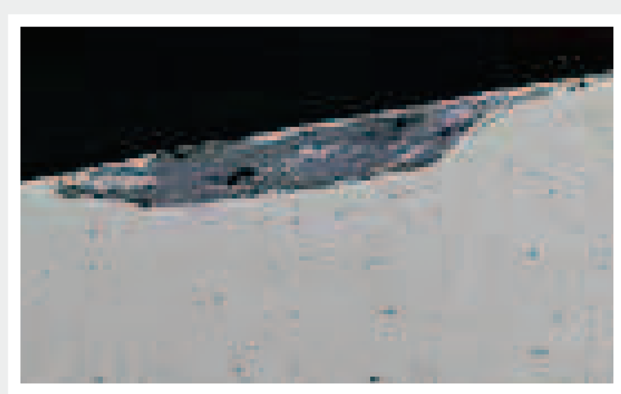


Figure 2 - Typical exfoliated copper oxide particle re-embedded in the rod from inadequate high pressure descaling

Magnet wire – By courtesy of Lac Sim Co. (Iran)

ing rolling and frequently produce ductile wire breaks. Since it is caused by an insufficient supply of molten metal, solidification should be complete before the cast bar exits the casting wheel, but preferably close to the 6 o'clock position. Adverse heat transfer for cooling of the casting wheel occurs if hard water deposits form on the wheel. Filtration of the cooling water will lead to improved rod quality and longer wheel life. It should be noted that only a small amount of superheat (40 °C), or temperature above the melting point, should be maintained to avoid hot-bar cracking or heat extraction problems with the molten copper. Another cause of a hot-crack, such as shown in **Figure 1**, is induced by high tensile stresses on the hot cast bar and may occur when the molten copper penetrates into cracks in the casting wheel. Once again these bar cracks are quite deep and lead to SSO's. Although corners of the cast bar are frequently trimmed by a scalping or bar preparation machine because of exuded flash, oxide particles are sometimes observed at these locations, and are associated with cracks that form during a torsional twist test on the rod.

Hot Rolling: as discussed previously, brittle wire breaks may occur if SSO's are present, and they can be caused by hot-cracks or faulty bar corners. In addition, both uniform surface oxides (USO's) and SSO's may form on the rod if the descaler in the roughing mill does not efficiently remove the surface copper oxide scale. Most of this scale can be easily removed by spraying the liquid rolling emulsion with a high pressure pump onto the copper when it is at a temperature of about 800 °C, i.e., in the roughing mill. Care must be taken to ensure that none of the exfoliated scale becomes re-embedded onto the surface of the hot copper during further rolling. **Figure 2** shows a typical copper oxide particle that was rolled onto the rod surface. Should this issue occur, the USO thickness will increase greatly and result in excess fines generation during wire drawing. Although ASTM rod standard B49 allows a maximum value of 750A, high quality rod oftentimes has an USO number below 100A. The weight of copper fines on rod exhibits a linear relationship with the USO thickness. Slivers and seams may also be caused by SSO's, which makes the drawn wire crack and split apart. If tool steel rolling mills and guides in the roughing mill are left in service too long, thermal fatigue cracks will form and cause magnetic inclusions to form that become embedded in the surface of the moving rod. On the other hand, thermal fatigue and erosion will cause pits to form in the finishing rolls. These surface pits become filled with copper and will be deposited as eruptions on the rod. Overfills may occur when the rolls are misaligned and appear as longitudinal ridges on the rod surface that run parallel to the rolling direction. Overfills can also occur when significant changes are made to the rolling mill. Under these conditions the volume of metal being deformed at each stand may not be the same, resulting in either rod tensile cracks or cobbles in the rolling mill. To prevent these problems, a mill constant analysis should be performed on a fishpole.

In summary, copper rod that is used for multiwire drawing needs to have maximum premium quality, and should be similar to coils used for magnet wire products. All of the detrimental problems discussed heretofore should be addressed, and coils should not be used for these two applications if they are produced just prior to shut down or upon immediate start-up. The rod producer should examine all process and rod wire breaks, measure the thickness of USO and SSO's, perform mill constant analyses periodically, make twist tests, calibrate all eddy-current coils using man-made artificial discontinuity standards, and conduct metallographic analyses of both sound and defective rod and wire samples.

By H.P.

Copper rod coils before break-down operation