SOME TIPS ABOUT THE CLASSIFICATION OF WIRE BREAKAGES – PART B

Figure 1 – Typical cuppy wire break

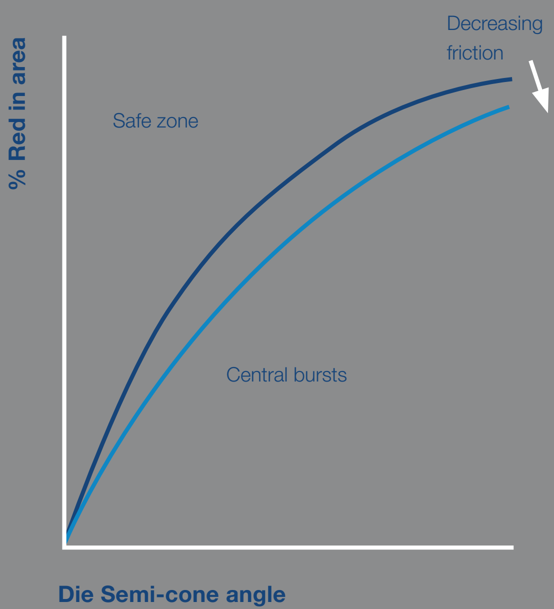

Figure 2 – Schematic curve illustrating the relationship between reduction in area during wire drawing and the corresponding die semi-cone angle

Central bursting, oftentimes referred to as "cuppy" wire, is associated with a brittle type of fracture that has both a cup (or hole) end and a mating cone end. A typical cuppy wire break is shown in **Figure 1**. Cuppy wire is classified as drawing related because it is caused by poor die geometry, such as a very low reduction in area or a large reduction zone die angle. A schematic curve illustrating the relationship between reduction in area during wire drawing and the corresponding die semi cone angle is shown graphically in **Figure 2** with friction being a variable process parameter. No central burst is expected above or to the left of the frictional curve. However, one should anticipate central bursting to occur both below and to the right of the appropriate curve. The danger zone usually becomes smaller as the coefficient of strain hardening becomes larger. A very small area reduction at any die causes the surface of the wire to move at a faster velocity than its center, and consequently introduces a high tensile stress at the center of the wire. When this stress becomes large enough, the fracture stress of the wire may be exceeded, which will nucleate a crack. As wire drawing proceeds, the crack gradually propagates on a 45 degree shear plane with respect to the drawing direction, and eventually results in a cup and cone type of fracture with the cone end pointing in the direction of wire drawing. **Figure 3** is a metallographically prepared cross-section of a copper wire that has been taken at its center soon after the initiation of central bursting. Since copper is quite ductile, complete separation does not usually occur until the wire has been drawn through many dies. In fact, if the crack initiates within the rod breakdown machine but does not progress sufficiently to induce fracture by the last die, the process wire may break in the secondary wire drawing machine or later. However, since the direction of drawing is now reversed, any internal V-shaped crack will point in the opposite direction of wire drawing, and the resulting cup end of the break that is left in the machine will now point in the wire drawing direction. If conditions for central bursting are prevalent in both the rod breakdown machine and the subsequent secondary wire drawing machine, V-shaped cracks will point in both directions. This is illustrated by the photomicrograph in **Figure 4**. Cups occur in the center of the wire and look almost identical to that of macroporosity (hollow end) breaks and similar to some inclusion absent and ductile tensile breaks. Consequently, it is oftentimes very difficult to make a distinction between cups and macroporosity breaks, even though there is less reduction in area at the cup end.

In addition to poor die geometry, several other factors can exacerbate central bursting. For example, if macroporosity is present in the redraw rod because of poor solidification practice, cracks do not have to be nucleated. Many cone breaks are present that have a casting related void near the tip of the fracture, as may be seen in **Figure 5**. High equilibrium oxygen contents in copper decrease formability and ductility, and allow cracks to propagate more easily throughout the wire. Consequently, ETP copper having high oxygen contents are more likely to fail by central bursting than OF copper. Even when new draw dies have proper reduction angles and are designed for normal B&S (Brown and Sharp system for wire sites) reductions, the formation of cuppy wire breaks can still occur sporadically. For example, if a die is left in service too long and exhibits extensive die wear, the area reduction will diminish to a point where central bursting is likely. Another problem can occur with the hot-welding process. If excessive exuberance is exercised by the operator when filing off flash at the butt joint, the copper rod diameter at this location will be reduced. Because of reduced area reduction at the first draw die, central bursting cracks may form inside the conductor. It is also important to note that a high coefficient of friction during wire drawing will decrease the safety margins for both area reductions and drawing angles.

In summary, prevention of central bursting is dependent upon three factors, namely, proper geometry of the draw die, high incoming rod quality, and adequate lubrication. If only one of these variables is marginal, it is possible to achieve sound drawn wire. However, should two of these variables be marginal, it is likely that central bursting may occur occasionally. Central bursts are of great concern because they are not easily detected, but usually cause unexpected failure of the wire in service.

by Horace Pops

Figure 5 – Cone break initiated by macroporosity

Figure 3 – Metallographically prepared cross-section of a copper wire

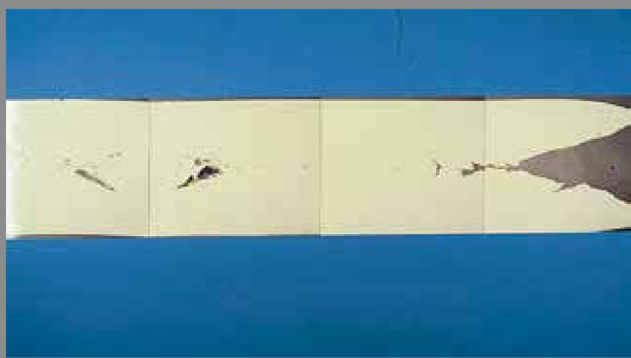

Figure 4 – Photomicrograph illustrating wire cracks pointing in both directions