# MAGNET WIRE; A VERY DEMANDING APPLICATION FOR ETP COPPER ROD



Several technologies are presently considered mature since they have been in use for several decades. Nevertheless, even mature technologies are still subjected to technical and technological improvements with the aim of improving the level of safety and the index of repeatability of quality while reducing the transformation costs.

The production of ETP copper rod on a continuous basis, using Properzi Rod Lines, began during the 1960s, thereby making the process of rolling wirebars obsolete.

It has therefore been many years since copper rod became available worldwide in the form of coils having a weight ranging from 3,000 kg to 5,000 kg with standardized geometrical dimensions. Currently, only two main technologies are used for producing copper rod: the Up Cast Unit and the Continuous Casting & Direct Rolling System based on either the Wheel and Belt Caster or on the Twin-Belt Caster followed by rolling mills with three-roll rolling technology, two-roll rolling technology or a combination of the two.

As we know, copper rod is used mainly for electrical applications, namely cable, bare conductors and magnet wire.

Available data shows that between 57 % and 60 % of the total copper consumption worldwide is absorbed by the market in the form of rod. Of this amount 23 % is used for the so-called magnet wire applications (motors and transformers for example).

After reviewing available statistics, we know that the total copper consumption was slightly below 21 million tons in 2012. Therefore, we can estimate that the portion of rod used for magnet wire applications was in the range of 2.9 million tons. This is indeed a large amount!

Before the copper wire is wound, the wire is coated with a thin layer of insulation to protect the users and the components within the device from the electricity that passes through it. Magnet wire is then wound into a coil in order to produce electromagnetic effects, although the wire itself is not magnetic. Magnet wire can convert an electrical current into a magnetic field. Copper rod used for magnet wire applications must have some special characteristics that will be described in this article.

In summary:

**Mechanical Properties**
- >> Low yield strength
- >> Low springiness

**Physical Properties**
- >> High electrical conductivity
- >> Annealability behavior
- >> Low recrystallization temperature
- >> High purity of copper
- >> Good conformability

**Surface Characteristics**
- >> No surface defects caused by mechanical damage
- >> Thin surface oxide layer

**Drawability**
- >> Controlled total oxygen content
- >> Absence of foreign inclusion(s)
- >> No internal porosity

Most of these properties and characteristics are controlled during the process used to obtain rod and wire in terms of rate of reduction (cold and hot), cycles of annealing temperatures, etc.

It is now very important to review the various factors affecting the rod quality:

***• Effects of Impurities***

Purity of the copper cathodes is one of the most important factors affecting the softening behaviour of the copper rod for magnet wire applications.

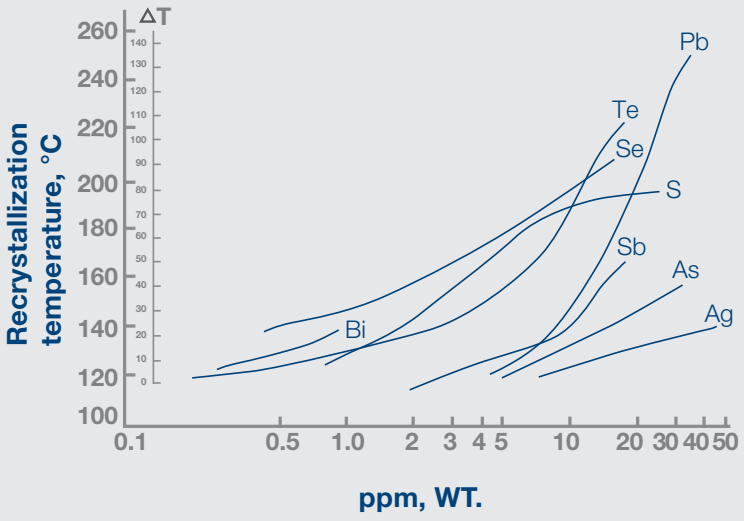


**Figure 1 - Effect of impurities upon annealing temperature of high-purity tough-pitch copper**

Typical applications of magnet wire



Figure 1 shows the effect such impurities, in varying quantities, can have on the recrystallization temperature.

It should be noted that most elements are harmful for magnet wire applications because they delay the softening and increase the electrical resistivity.

**• *Oxygen Content***

The single most important element in ETP copper rod is the total oxygen that is normally added as a gas phase to the melt.

Although, oxygen has very little influence on the annealing temperature of ETP copper, oxygen in combination with other metallic impurities plays an important role in affecting ductility, conductivity and drawability. The annealing temperature will be lower when insoluble oxides are formed at the grain boundary.

**• *Surface Oxide***

During casting and high temperature exposure to air, hot rolled copper rod develops a black surface oxide. The modern in-line alcohol deoxidizing systems reduce the oxide thickness on the finished ETP copper rod to less than 200 Å.

In the organic reduction method, by alcohol, a thin film of reduced copper usually covers a subsurface layer of oxide, as shown in Figure 2.
This condition, together with the inherent brittle nature of copper oxide, leads to the formation of fine particulates during subsequent twisting or wiredrawing.

Additional problems that may arise from excess surface oxides are:

- rapid die wear
- deterioration of the wiredrawing emulsion

When acid pickling is used, particles of rolled-in oxide scale are completely dissolved thereby leaving small pockets on the copper rod surface.

In summary, first and foremost the highest quality cathodes and the best quality ETP copper rod are required for the production of magnet wire. The quality demand is so rigorous that most copper rod producers need to implement a very efficiency and stringent quality procedure able to assess and select different copper rod quality grades suitable to satisfy all segments of the wire industry.

This quality procedure will verify rod characteristics including impurity levels, comparable to those found in Cu-CATH1 cathodes, electrical conductivity, size and out of roundness, surface oxide film thickness, oxygen content, as well as outline a procedure for the Twist-Test and Spiral Elongation Number.

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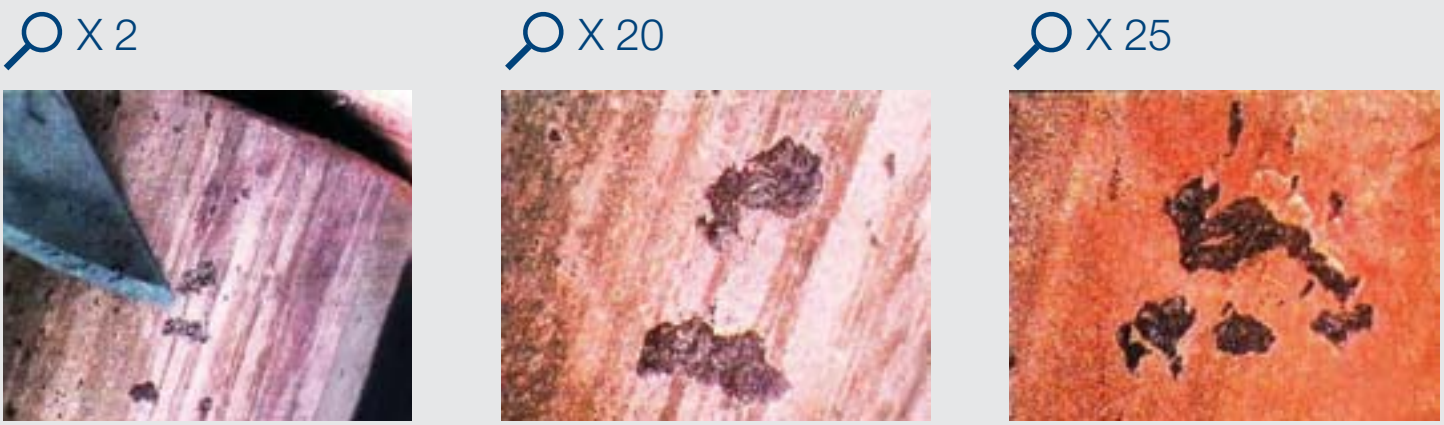


Figure 2 - Subsurface oxides on the alcohol deoxidized ETP copper rod