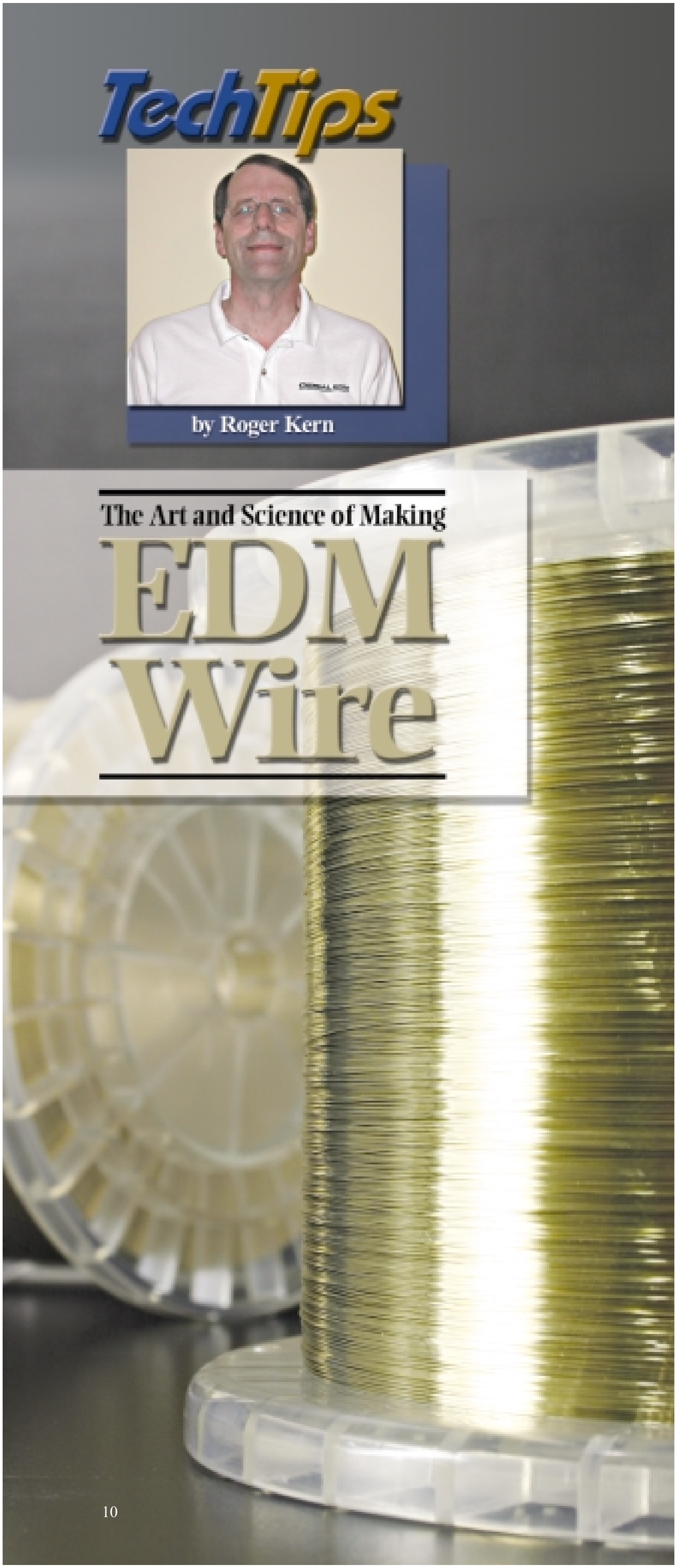


TechTips

by Roger Kern

TechTips is a collection of useful ideas, techniques, and procedures designed to further EDM knowledge.

The Art and Science of Making EDM Wire

The manufacture of the EDM wire that we use every day is far more complicated than most of us imagine. This article will embark on a tour of the process of making EDM wire, from raw materials to finished packaging; hopefully imparting a better understanding of what goes into the product on which an entire industry depends.

The first part of our tour will feature a detailed look at how brass wire is made. Later, we'll explore the additional steps employed in the manufacture of coated wires.

BRASS WIRE

The manufacture of brass EDM wire (similar steps are applicable to copper EDM wires) can be divided into the following primary activities:

- Casting
- Rolling
- Preliminary Drawing
- Finish Drawing
- Spooling
- Packaging

Casting

Brass EDM wire is an alloy of Copper and Zinc. The most common compositions range from Cu65:Zn35 to Cu60:Zn40. It should be noted that the composition is apportioned by weight. The Copper for this mixture usually takes the form of Copper cathode plates. The plates are called cathodes because the final refinement process in manufacturing copper is usually an electro-deposition process, in which the copper is formed on a cathode in a bath. Thus, the copper is often called electrolytic copper. The Zinc for this mixture is usually in the form of cast Zinc ingots.

Most all quality EDM wires are made from virgin raw materials, that is derived from ore and not from scrap. It is very important that the raw materials for EDM wire be as pure as possible. When copper and zinc are derived from scrap, there is always a possibility of contaminants carrying over into the finished product. As the old saying goes “Garbage in, Garbage out”. This also applies to EDM wires.

The raw materials are weighed out in the correct weight proportions and then placed in a crucible. The crucible is then heated by resistance elements or induction to liquefy the contents. Prior to casting each batch, a sample is drawn from the crucible and allowed to solidify. The sample is then taken to the lab for mass spectrographic analysis, where it is checked for alloy proportions and foreign elements that are considered contaminants. ***(See Fig #1)***

Sample Description: One (1) Wire Sample, Nominal Brass Alloy 270

CHEMICAL ANALYSIS BY ICP (SOP 10.23 R1)

Element	Result %	Min %	Max %
Pb	<0.01	0.00	0.10
Fe	<0.01	0.00	0.07
Cu	63.5	63.0	68.5
TNE	99.9	99.7	-
Zn	Balance	Balance	
TYPE	C270 UNS C27000		

Figure #1

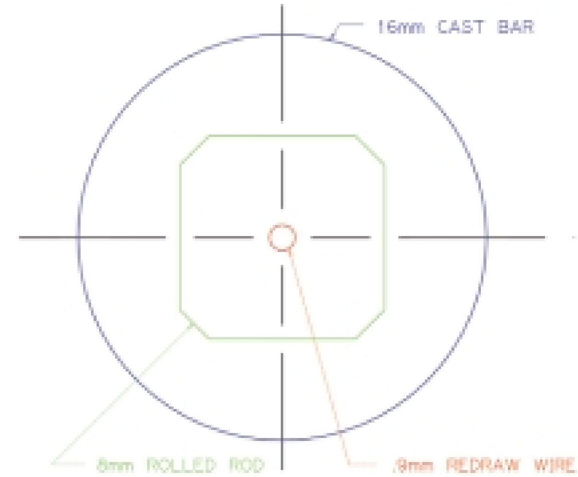


Figure #2A

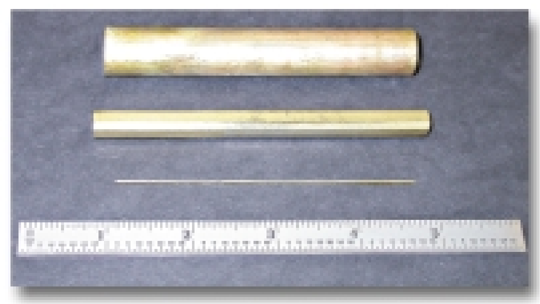


Figure #2B

Once the lab sample is approved, the casting can begin. The production of most quality EDM wires begins with the continuous casting method. Continuous casting is an uninterrupted process in which molten material is poured from the crucible into a reservoir in a water cooled graphite mold, which contains passages which transform the molten the metal into a continuous solid cylindrical rod. ***(See Fig#2A & Fig#2B)*** The rod exiting the mold (which is often about 16mm diameter) is cooled in air and then coiled onto a large reel. Careful control of the parameters of this process is required to ensure that the properties of the rod, such as grain size and material integrity, are optimized for the numerous subsequent operations.

Rolling

These huge coils are then brought to the rolling mill, where the cross section is reduced to a size which is suitable for the first drawing operations. The actual shape of the cross section varies by manufacturer, with a modified square being one of the more common cross sections. After passing through a series of rolling stations, the cross section is reduced from approximately 16mm to 8mm, and the wire is again wound on large reels. As the wire is severely deformed during the rolling process, its hardness increases to the point where no

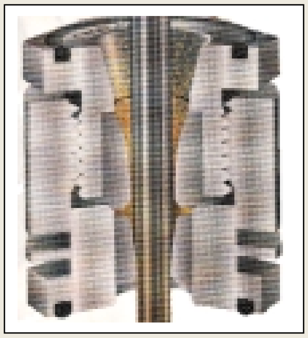


Figure #3

further processing can occur until it has been annealed. The reels are loaded into a large furnace, where they are brought to the re-crystallization temperature and then slowly cooled to soften the material, to enable further processing. At this point, another sample is then taken to the lab to check for metallurgical integrity and grain size.

Preliminary Drawing

After annealing, the square wire is pulled through a series of draw dies (typically ten to twenty) while immersed in special lubricant to reduce its cross section to approximately .9mm diameter. The amount of reduction between each die, the speed of the drawing, the type and condition of the lubricant, the geometry of the draw die openings ***(See Fig#3)***, and the draw die material, all play a crucial roll in the quality of the finished product. There may also be additional annealing steps during this preliminary drawing process. The end product is then sampled in the lab and checked for metallurgical integrity, grain size, surface finish, tensile strength, and elongation. The output product of this stage of the production is called “redraw wire”.

It should be noted that, due to the capital intensive nature of the casting, rolling, and preliminary drawing processes, many wire manufacturers do not produce their own redraw wire, but buy it from mills specializing in this product. Thus, it is extremely critical that non vertically integrated manufacturers, who do not produce their own redraw wires, purchase their redraw wire from selected high quality mills, as it is impossible to produce a consistently high quality EDM wire from variable quality redraw wire.

Finish Drawing

The process of taking the wire from .9mm to its finished size is finish drawing. Finish drawing operations are similar to preliminary drawing operations, except that all parameters of the finish drawing operation need to be tightly controlled, since the output of this process is the finished product. The redraw wire is passed through a series of approximately ten to twenty draw dies while immersed in special lubricant. In the finish drawing operation, the insert material for all the draw die stations is either synthetic or natural diamond.

The conditioning and maintenance of the drawing lubricant is especially critical during the finish drawing process. As the cross section of the wire is reduced, microscopic flaws in the draw die surfaces can produce brass powder which must be filtered from the lubricant, lest it be drawn into the next station. Also, since the lubricant absorbs much of the heat from the drawing process, its temperature must be tightly controlled.

The ultimate straightness of the finished EDM wire is determined by the last draw station in the finish drawing process. The position and attitude of the last drawing die insert is adjusted to produce a straight wire. There is no straightening process in EDM wire drawing. The wire either comes out straight, or it does not.

The condition of the wire after coming out of the final draw die is hard and brittle, as a result of all of the cold work deformation in the finish drawing process. (It should be noted that there are no intermediate heat treatment steps in the finish drawing process). Thus, the wire must undergo an annealing process immediately after finish drawing to bring it to the desired hard, half hard, or soft temper conditions required by the application. This annealing process varies with the manufacturer.

Some manufacturers resistance anneal the wire by passing an electric current through the wire while it is submerged in water based coolant. Other manufacturers pass the wire through a furnace in tubes that are shielded with an inert gas to prevent oxidation.

Regardless of the annealing operation, the wire is cleaned, dried, and wound onto an “intermediate” spool of approximately 100-200kg, prior to spooling.

Prior to spooling, samples of the finished wire are sent to the testing lab to check:

- Diameter
- Ovality
- Tensile Strength ***(See Fig# 4)***
- Elongation
- Straightness
- Cleanliness
- Surface Condition

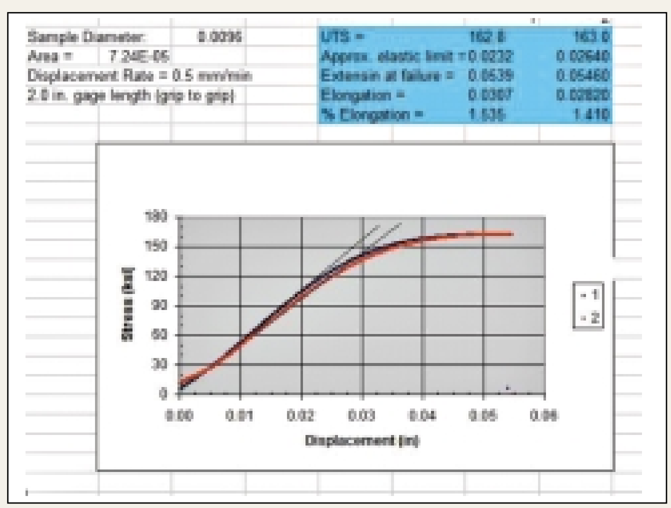


Figure #4

Spooling

At this point in time you might be thinking "Now that the hard part is finished, this should be easy!" Did you know that more EDM wire is rejected by customers for issues related to improper spooling than any other reason? It's true!

Before the spooling process begins, the spools themselves need to be inspected.

- Is the spool barrel concentric to the datum "centers"? (These are the chamfers on each end of the through hole in the center of the spool)
- Are the spool flanges parallel, and do they run true to the centers?
- Are there any molding knit lines or flash that could interfere with the smooth spooling or unwinding?

Spooling is like winding up line on an old fashioned fishing real, except that spooling needs to be an exacting, controlled process. If the wire does not pay off smoothly and without tangles, the spool is useless, because valuable production time is often lost when a machine shuts down due to spooling issues.

One of the most critical operations in the spooling process is to set the traverse reversal points so that they exactly match the flanges of the spool. If the reversal point is set beyond the flange location, the wire will climb up upon itself at each reversal, often causing machine stopping overwraps. ***(See Fig# 5)*** If the reversal point is set short of the spool flange, the reversal coils can irregularly spill over beyond the reversal point resulting in overwraps. ***(See Fig# 6)*** If the set distance between the reversal points matches the distance between the spool flanges, but is not centered between the spool flanges, both of the previously mentioned conditions will be observed on the same spool. ***(See Fig# 7)*** The ideal spooling condition is achieved when the reversal point is set ever so slightly inside of the spool flange wall. ***(See Fig# 8)***

Many people think that the traverse rate (or winding pitch) on a spooling machine is set so that the coils are neatly adjacent to each other. This is usually not the case. Setting the correct spooling pitch for smooth spooling and unwinding is part of the "art" and one of the numerous trade secrets in the wiremaking process. Usually, the spooling pitch is several times the wire diameter. ***(See Fig# 9)***

Spooling winding tension is another process variable that is crucial to the successful unwinding of the wire when the spool is finally installed on the wire machine. If the spooling winding tension is set too high, the axial forces that develop after layer upon layer of wire is wound on the spool are additive, and can actually cause the flanges of the spool to

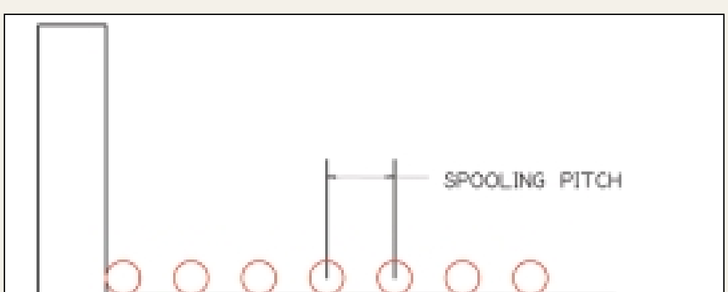


Figure #9

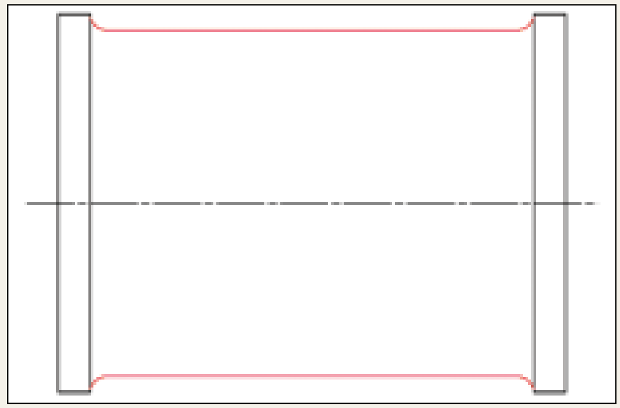


Figure #5

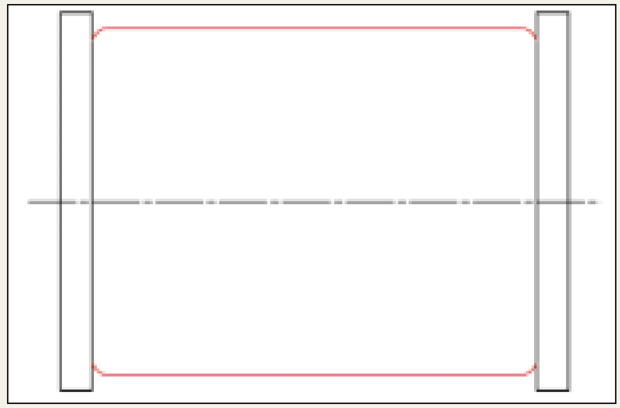


Figure #6

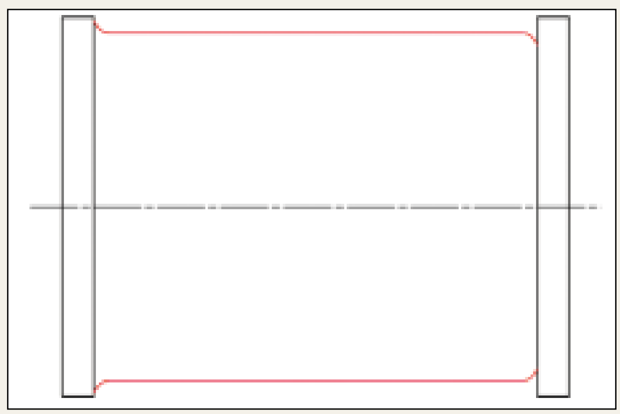


Figure #7

Figure #8

break off, often long after the spool is packaged and shipped. If the spooling tension is set too low, the adjacent coils can shift due to shocks in transit, and result in an overwrap or "tangled" spool before it is even removed from the box.

At one time, the EDM wire strand was sprayed with a thin coating of atomized paraffin just prior to being wound onto the spool. The addition of this lubricant was said to make the spooling and unspooling of the wire a much smoother process. It was also believed that the paraffin acted as a lubricant to the wire passing through the diamond guides. For poorly made wires, paraffin on the surface can also mask brass powder problems. Unfortunately, paraffin can cause operational problems in the wire EDM. Paraffin can accumulate on the rollers of a machine and cause tension problems due to slippage. Paraffin can also accumulate in the guide system, causing threading and maintenance problems. Finally, paraffin (which is an insulator) can interfere with the wire edge finding process when picking up the workpiece. Most modern, high quality EDM wires today are made without paraffin to meet the requirements for paraffin-free wire, set by many machine tool manufacturers.

Packaging

Wire packaging has two primary objectives:

- Protect the wire from oxidation and corrosion
- Protect the spool from impact damage.

Oxidation Protection

There are three ways in which wire manufacturers protect the wire from oxidation and corrosion:

- Add a desiccant package to the wire box to absorb moisture
- Shrink a plastic sleeve around the spool barrel and a portion of the flange
- Insert the entire spool in a plastic or foil bag, remove all the air, and seal the bag.

Obviously, the latter method provides the best protection at the expense of increased packaging cost.

Impact Protection

Have you ever watched the delivery man load or unload his truck. The box with your precious EDM wire is often subjected to very rough handling in shipment. Did you know that boxes can drop *two to three feet* between the conveyer belts that make up a modern distribution hub? Therefore, it is essential that the spool be packaged in such a way that it is buffered from this harsh treatment. This often means encasing the spool in a molded Styrofoam box ***(See Fig# 10)*** or providing cardboard formed cradles and spacers. In my opinion, nothing protects the wire like Styrofoam, however some countries, states, municipalities, and customers now ban its use in packaging. A well engineered cardboard box with properly designed cradles and fillers can provide adequate protection for a spool of EDM wire. ***(See Fig# 11)*** It has also been demonstrated that the shrink wrapping often associated with vacuum packing can securely hold the wire coils so that they are less likely to shift during severe shipping impacts.

Figure #10

Figure #11

coated wires

COATED WIRES

Virtually all coatings on EDM wires are based upon a Zinc layer. There are three basic types of coated wires:

- Zinc Coated
- Heat Treated Zinc Coated
- Multiple Layered Heat Treated Zinc Coated

The manufacture of these wires requires additional plating and/or heat treating steps to the process for "plain" brass (or Copper) wire described above. In this exercise we will not delve into the types and compositions of wires (See EDM Wire Primer — Properties of EDM Wires Jan/Feb 2007), but instead we will describe the processes used to manufacture them.

The most common misconception about coated EDM wires is that the wire is coated at the final diameter stage. This is generally not the case. The plating and/or heat treating steps are applied to the .9mm redraw wire, prior to the finish drawing.

Coating

The .9mm redraw wire is coated with Zinc by one of two methods:

- Hot Dip
- Electroplating

In the Hot Dip method, the wire is passed through a molten bath of Zinc, which adheres to the wire and then solidifies. The Hot Dip method is the most economical method of adding a Zinc coating to the wire, but accurately controlling the coating thickness and preventing pin holes with this method can be tricky.

In the Electroplating method, the wire is passed through a chemical plating bath while an electric current is imposed upon it. The zinc ions in the bath are plated onto the surface of the wire. Since the deposition rate of electroplating is dramatically slower than that of hot dipping, the bath can be in excess of 100 feet long, and the wire makes numerous passes back and forth through the bath. Electroplating offers very precise control of coating thickness.

Coating thicknesses on the redraw wire can range from 10 to 50 microns.

Heat Treating

The Zinc coating on a coated wire is often heat treated to improve its cutting properties. During the heat treatment process (called diffusion annealing), the molecules of the core material and coating material intermingle as a result of the concentration gradient at their boundary. The result is that the pure Zinc coating is transformed into a Zinc rich alloy of either beta or gamma brass.

Heat treating the coated re-draw wire is accomplished by one of two methods:

- Batch Heat Treating
- Continuous Heat Treating

In the batch heat treating process, a coil of the coated redraw wire is placed into an atmosphere controlled furnace and brought to a certain temperature for a certain amount of time, all the while protected from ruinous oxidation by an inert atmosphere or vacuum.

In the continuous heat treating process, an electric current is passed through the wire as it passes between two sets of rollers and it is heated while protected from the atmosphere by a shield gas. The magnitude of the current, the length of the path, and the speed of the wire are the critical parameters for this method.

Needless-to-say, for multiple coated, heat treated wires, the entire coating and heat treating process is repeated twice.

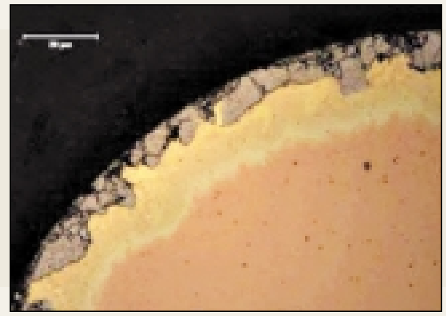
Final Drawing Considerations for Coated Wires

Performing the final drawing operations on a coated re-draw wire adds a considerable level of difficulty and complexity to the final drawing process.

Reducing the diameter of the coated re-draw wire by a factor of four while maintaining a uniform coating thickness without stripping off the coating (which may become quite brittle after heat treatment) is a daunting engineering challenge.

After final drawing, the wire is sent to the metallurgy lab, where a small sample is mounted in plastic for cross-sectional analysis. A photomicrograph is taken and analyzed to check coating uniformity, thickness, and complete heat treatment conversion of the coating. (See ***Fig# 12*** which depicts a double coated, heat treated wire.)

Figure #12



Conclusion

The high precision EDM wire that we depend upon, but often take for granted, is the marvelous result of the successful combination of a huge capital investment, high level engineering, centuries of drawing art, and an unrelenting dedication to quality by an unheralded industry. In our industry where a critical job can be spoiled by just one of any number of possible wire deficiencies, the phrase "Penny wise pound foolish" should be kept foremost in mind when sourcing your EDM wire needs.

Any suggestions for future topics are welcome.
Tell us what you would like to read about.
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