Techtips

by Roger Kern

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

EDM Wire Primer

This issue we return our attention to a Wire EDM topic. We will delve into the subjects of Properties of EDM Wires and Types of EDM wires to help enhance your understanding of the numerous choices of EDM Wire available today. The following discussion, while somewhat technical in nature, is aimed at the toolmaker rather than the metallurgist.

Properties of EDM Wires

The following section describes the key physical properties of EDM wires and how they relate to real world cutting:

Conductivity is often expressed as a percentage of IACS, which is a comparison to the conductivity of pure annealed Copper wire (which is the reference standard of 100%). Conductivity is an important property of an EDM wire, since it determines how readily the power supply energy is transferred over the distance from the power feed contact to the actual point of cutting. This distance can be considerable, especially if the job is being cut with “open guides” to clear a workpiece obstruction. Low wire conductivity will result in a voltage drop and associated energy loss over the distance from the power feed to the cutting point. This is not insignificant when one considers that the peak current of most modern power supplies often exceeds 100 amps.

Tensile Strength indicates the ability of the wire to withstand the wire tension imposed upon the wire during cutting, in order to make a vertically straight cut. Since all commonly used wire EDMs are imported, tensile strength is most commonly specified in the metric units of N/mm^2. EDM wires are considered “hard” at tensile strengths of 900 N/mm^2 or above. EDM wires are considered “half hard” at tensile strengths at or about 490 N/mm^2. EDM wires are considered “soft” at tensile strengths at or below 440 N/mm^2. (Unfortunately, the nomenclature for “half hard” and “soft” has different meanings in Europe and Asia) Hard wires are commonly used for most work, while half hard and soft wires are primarily used for taper cuts where the taper angle is greater than five degrees, since a hard wire will resist bending at the guide pivot and will result in inaccurate taper cutting. Half hard and soft wires are often unsuitable for automatic threading unless the machine is specifically design to work with these wires.

Elongation describes how much the wire "gives" or plastically deforms just before it breaks. Elongation is measured in % of the gauge length used in a given test. It could also be stated that elongation relates to how "brittle" the wire is. Usually, hard wires have elongation that is considerably lower than half hard wires. Elongation is an important property, since EDM wire operates in a hostile environment in which it is under high tension and being "attacked" by thousands of sparks which are eating at its cross-section. A brittle wire might snap at the first overload condition, while a more ductile wire is more likely to accept a temporary overload by "giving" a little and continuing to cut.

Melting Point is not normally specified for a given wire, but is obviously important since EDM is a spark erosion process, and we would prefer that our wire electrode be somewhat resistant to being melted too quickly by all those sparks.

Straightness is another important property of EDM wire that is seldom specified but is critically important to successful autothreading.

Flushability is normally not specified for a given wire, but is an important property that relates to how well a wire will actually cut. This property is related to the sublimation temperature of the wire's alloy components that is more in the realm of metallurgy than toolmaking. Let's just say that the better the flushablity, the faster the wire will cut.

Cleanliness is a property that is not specified for EDM wires. Wire can be "dirty", due to contamination by residual metal powder left over from the drawing process, drawing lubricant, or paraffin added to the wire by some manufacturers prior to spooling. Dirty wire can ruin your day, resulting in clogged guides and power feeds or slipping belts or rollers.

Like most other things in life, finding the best wire for any application means finding an acceptable compromise of the aforementioned properties, since they are often contradictory. For example, high conductivity wires often have low tensile strength.

Wire Types

Before we proceed, a brief discussion on the manufacturing process for EDM wire is in order. Typically, Brass wires start out as a continuously cast 20mm diameter rod. This rod is either cold rolled or cold drawn until it is approximately either a 6mm round or hex cross-section. The wire is then annealed and drawn through a series of dies until it is approximately .9mm diameter. In this state, it is commonly called "re-draw" wire. The re-draw wire is subsequently drawn through another series of diamond dies until it is the final size. At final size, the wire is either resistively annealed or thermally tempered in an inert atmosphere, cleaned, and then spooled.

• Plain Wires

While in the fashion world plain might be a derogatory term, in the EDM wire business "plain" merely means that the wire consists of a single homogeneous component and does not have a coated or composite construction.

Copper Wire was the original EDM wire. At the time it was thought that since Copper wire had high electrical conductivity, it would make the ideal EDM wire. Unfortunately, Copper wire has both low tensile strength and low flushability. This soon became apparent with the development of the 2nd generation pulse type power supplies and Copper wire was soon supplanted by Brass wires. It should be noted that Copper wires are still used occasionally for applications in which Zinc (contained in brass wires or coated wires) is considered an unacceptable contaminant.

Figure 1

Brass Wire ***(See Fig. 1)*** was the successor to Copper wire and is still the most commonly used wire today. Brass, which is an alloy of Copper and Zinc, delivers a powerful combination of low cost, reasonable conductivity, high tensile strength, and improved flushability. (It should be noted that even a small amount of Zinc added to Copper wire drastically reduces the conductivity. Hard Brass wire typically has a conductivity only 20% of Copper wire.) Brass wire is most commonly available in the following alloys:

European: Cu63%Zn37%

Asian: Cu65%Zn35%

Since it is the Zinc that gives Brass Wire its improved flushability, some manufacturers now offer a "high zinc" brass which is Cu60%Zn40%. This increase in Zinc content can increase cutting speed up to 5% in some optimized applications, however, many users who are content to use "standard" settings may not see a cutting speed increase. It should also be noted that in certain circumstances, a significant Brass deposit can remain on the workpiece after the cut, that can prove to be quite difficult to remove.

One might ask that if higher Zinc alloy content leads to increased cutting speed, why not merely produce a Brass wire with a Zinc content of greater than 40%? Unfortunately, it is not practical to cold draw wire with Zinc content in excess of 40%. This fact led to the development of coated wires which we will discuss shortly.

Figure 2

Aluminum Brass Wire

(See Fig. 2)

The addition of a small percentage of Aluminum to a Brass wire creates a specialty alloy wire commonly known as Somsal, TAF, and other brand names. These alloy additions improve the tensile properties of the wire allowing the tensile strength to be brought up to as high as 1,200 N/mm^2 without adversely affecting elongation. Some users claim that these wires are less susceptible to breakage than other types of plain Brass wire. Usage of this type of wire has fallen off to the point that one major manufacturer has announced plans to discontinue it.

Molybdenum Wire is used in limited applications which require very high tensile strength to provide a reasonable load carrying capacity in small diameter wires. "Moly" has both a high melting point and high tensile strength. It is often used for small diameter EDM wires, .004" and under. Unfortunately, Moly Wire has both low electrical conductivity and very low flushability. In addition, Moly Wire is very abrasive to power feeds and wire guides, and is often difficult to autothread. Finally, Moly wire is very expensive.

Tungsten Wire has even greater tensile strength and a higher melting point than Moly wire. Tungsten Wire is often an economical (relatively speaking) alternative to Moly Wire in diameters .002" and smaller.

• Coated Wires

Since we have already noted that it is not practical to produce a "plain" brass wire at alloy percentage greater than 40% Zinc, coated wires were developed in an attempt to put Zinc on the surface of the wire, while retaining a core wire material that could be successfully drawn. Coated wires are produced by plating or hot-dipping re-draw wire (.9mm) and subsequently drawing it to final size. This is a difficult process, since the plated surface Zinc has to "survive" the final drawing process and still present a uniform coating to the cut. Currently, no EDM wires are manufactured by a process in which the coating is deposited at finish wire size.

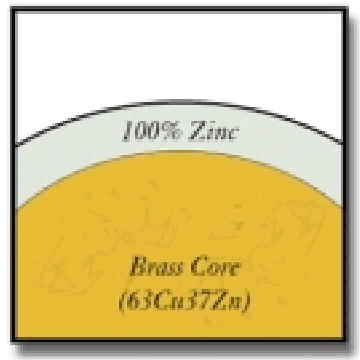

Figure 3

Zinc Coated Brass

(See Fig. 3)

Zinc coated Brass wire was one of the first attempts to present more Zinc to the wire's cutting surface. This wire consists of a thin (approximately 5 micron) zinc coating over a core which is one of the standard EDM brass alloys. This wire offers a significant increase in cutting speed over plain brass wires, without any sacrifice in any of the other critical properties. Zinc Coated Brass wires produce exceptional surface finishes when cutting Tungsten Carbide and are often utilized for cutting PCD and graphite. These wires are also utilized in those circumstances in which brass wires produce an unacceptable Brass plating on the workpiece.

Zinc Coated Copper EDM Wire was another early attempt to combine the conductivity of a Copper core with the flushability of Zinc. This wire was used only on early vintage Charmilles machines. It has no current application, since when the sparks penetrate the thin Zinc coating, the cutting rate slows to the tortoise pace of pure Copper wire.

• Diffusion Annealed Coated Wires

If Zinc has such great flushability (Cadmium and Magnesium are better, but Cadmium is a toxic metal and Magnesium is a dangerously reactive metal), one would think that a pure Zinc coating would produce the ultimate wire. In theory perhaps, but in reality it doesn't quite work out that way. Because Zinc has a low melting point and it is only plated onto the surface of the core wire, the intensity of the spark discharges tends to blast the Zinc off the surface of the wire core before it has a chance to live up to its full potential.

So, we need a coating with a high Zinc content and a relatively high melting point, which will result in good adherence to the core wire.

All these things can be achieved by heat treating the Zinc coated wire (at .9mm diameter). This process is called Diffusion Annealing. Under the right conditions at a controlled elevated temperature, and in an inert gas environment, diffusion will occur. Diffusion is the process whereby atoms diffuse from areas of high concentration to areas of lower concentration. In our case, the Zinc atoms diffuse into the Brass, and the Copper atoms from the Brass diffuse into the Zinc. This diffusion process transforms the Zinc coating into a high Zinc alloy Brass which is Zinc rich, has a relatively high melting point, and is metallurgically bonded to the core material. Voila!! This is exactly what we needed.

Before we leave this brief excursion into metallurgy and return to the practical application of all this theoretical stuff, we need to define the names for the various alloys of Brass and their associated properties:

• Alpha Brass (α):
An alloy of Copper and Zinc in which the Zinc percentage can range up to 39%. Plain Brass wire is Alpha Brass.

• Beta Brass (β):
An alloy of Copper and Zinc in which the Zinc percentage can range from 40% to 53%.

• Gamma Brass (γχ):
An alloy of Copper and Zinc in which the Zinc percentage can range from 57% to 70%. Gamma Brass is very brittle.

It should also be noted that each of these phases of Brass has a unique crystal structure which give the phase unique properties. (Similarly, depending on its crystal structure, Carbon can be either a lump of coal or a diamond.)

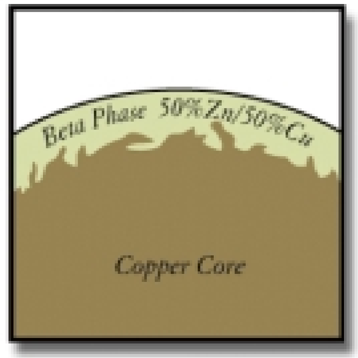

Figure 4

Figure 5

X-Type Wire *(See Fig. 4)*

This was the first diffusion annealed wire and is commonly known as SWX, BroncoCut-X, BetaCut-X, X-Kut, and other brand names. The wire consists of a Beta Brass coating over a pure Copper core. X-Type wire was originally developed for Charmilles machines. It has the advantage of the combination of the high conductivity of Copper and a tenacious Zinc rich coating. Its disadvantages are a tensile strength equivalent to half hard Brass combined with poor straightness and high cost relative to Brass wires. It will not auto-thread on most non-Charmilles machines. However, it produces significant productivity gains in aerospace alloys such as Inconel and Titanium, on virtually any machine, if you can live with the threading issues.

D-Type Wire *(See Fig. 5)*

This was the second diffusion annealed wire and is commonly known as CobraCut-D, D-Kut, and other brand names. The wire consists of a Beta Brass coating over a Copper core alloyed with 20% Zinc. D-Type wire was originally developed for Agie machines. It has the advantage of the combination of improved conductivity of the 80:20 Copper core, a tenacious Zinc rich coating, and relatively high tensile strength (800 N/mm^2). It will also auto-thread on most machines. Its disadvantage is its high cost. This wire produces significant productivity gains in virtually all materials and on many different machines.

• Gamma Coated Wires

The unrelenting drive for higher cutting speeds has led to the development of Gamma coated wires, since Gamma phase Brass has a higher Zinc content than Beta phase Brass. Gamma phase Brass is very brittle, and therefore the Gamma coating thickness is usually limited to less than 5 microns, since thicker coatings will fracture and strip off in the final drawing process. Due to the brittleness of the Gamma phase Brass, it actually fractures during the final drawing process producing a somewhat discontinuous surface (slightly cracked). This discontinuous surface has the benefit of increasing the cutting speed by improving the flushing as the wire passes through the cut, improving water flow and scouring the debris from the gap. The discontinuous surface has the disadvantage of being slightly dirtier than other Zinc coated wires.

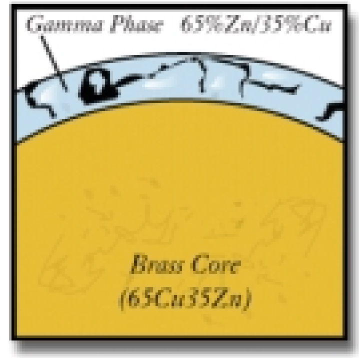

Figure 6

Gamma Brass Type Wire *(See Fig 6)*

This wire features a Brass Core and a Gamma phase Brass outer layer and is commonly known as Z-Kut, Topaz, Gamma-Z, DeltaCut, and other trade names. It is similar to Zinc coated Brass wire, except that the pure Zinc coating is replaced by a Gamma phase Brass coating. It is available with both hard and half hard Brass cores. Its performance is typically 10 to 25% faster than pure Zinc coated wires. Note, Gamma Brass type wires are available with a variety of Brass core compositions.

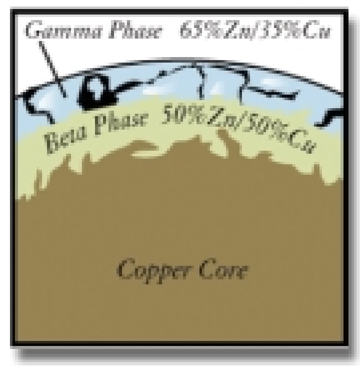

Figure 7

Gamma X Type Wire *(See Fig 7.)*

This wire features a Copper Core, a Beta phase Brass intermediate layer, and a Gamma phase Brass outer layer, and is commonly known as Gamma-X. It can be thought of as a traditional X-Type wire with an additional layer of Gamma phase Brass. The Beta phase layer is retained because it serves as a “backup” to the thin Gamma phase layer, in case the discharges break through it. It can be used in the same range of applications as traditional X-Type wires, but offers enhanced performance of approximately 10%. It has the same limitations on both tensile strength and threading as traditional X-Type wires, due to its pure Copper core. Its performance is exceptional on aerospace alloys, especially under good flush conditions.

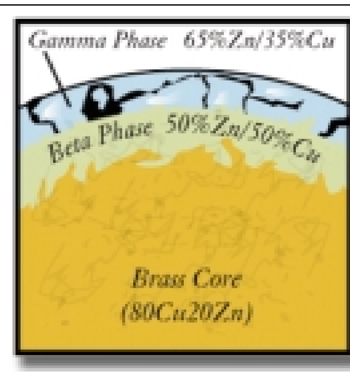

Figure 8

Gamma D Type Wire
(See Fig 8)

This wire features an 80:20 Copper Core, a Beta phase Brass intermediate layer, and a Gamma phase Brass outer layer, and is commonly known as Gamma-D or Versacut-H. It can be thought of as a traditional D-Type wire with an additional layer of Gamma phase Brass. It can be used in the same range of applications as traditional D-Type wires, but offers enhanced performance of up to 10%.

• Composite Wires

Composite wires combine traditional EDM wire alloys with non-EDM materials to create EDM wires with unique properties for specialty applications.

Steel Core Wire *(See Fig 9.)*

As the type name implies, Steel Core wires utilize a steel core and are commonly know as Compeed, MicroCut, MacroCut, or other trade names. This wire type consists of a steel core, which offers exceptional tensile strength and ductility, a copper intermediate layer to provide conductivity, and a Beta phase Brass outer layer. This type of wire offers exceptional resistance to breakage for tall workpieces, interrupted cuts, or poor flushing conditions, while providing excellent performance. Its primary limitations are high cost, straightness issues, auto-threadability, and possible damage to scrap choppers due to the steel core.

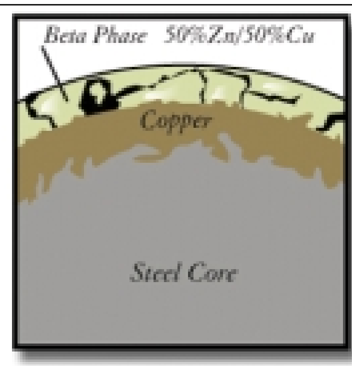

Figure 9

A Final Word

Diffusion annealed high performance EDM wires offer opportunities to significantly increase WEDM productivity. However, those who plan to merely substitute these wires for Brass, and just sit back and see big performance numbers may be sorely disappointed. While some OEMs offer new factory technology to take advantage of these new wires, in many instances, the maximum benefits will accrue only to those willing to try new parameter settings and "push the envelope".

Next issue, we'll explore some unusual and controversial application strategies to maximize the performance of most all types of EDM wires.

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