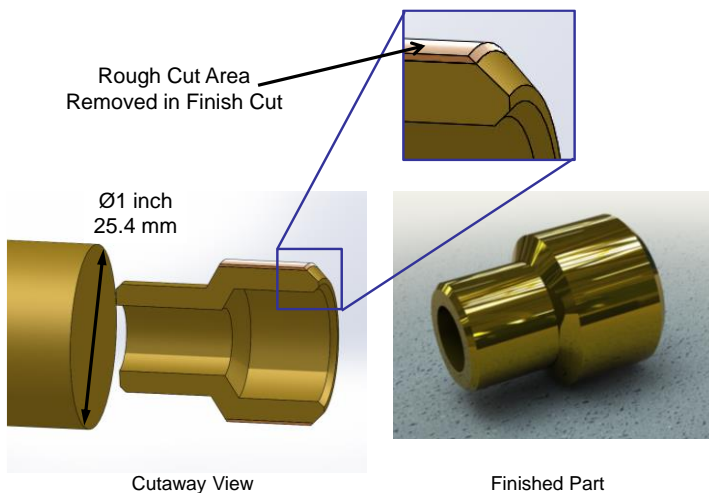


## Producing Good Screw Machined Parts from High Performance Copper Alloy Rod

Because of the necessity of heat treating, high performance copper alloy rod requires a little more care in machining. By following these guidelines, you should be able to produce good parts in your screw machining and heat treating operations.

### MACHINABILITY

The machinability of a given alloy depends on such factors as the operation type, tool life, tooling and tool geometry. A general machinability rating provides the designer with rough machinability guidelines for the available alloys. The machinability rating is determined through the procedure outlined in ASTM E 618. Machinability test specimens as shown in Figure 1 are machined out of 1 inch (25.4 mm) diameter rod. The machining speeds and feeds are adjusted to find the combination that provides a tool life of 8 hours. Tool life is measured by the length of time in which the test pieces produced are within dimensional and surface roughness tolerances. The maximum number of pieces produced per hour at a tool life of 8 hours becomes the machinability rating. It is expressed as a percentage of the number of pieces produced per hour by C36000 free-cutting brass, the most machinable metal.



**Figure 1.** This is the standard ASTM E618 machinability test specimen. The general geometry is rough cut, and a finishing cut removes the indicated area. The ratio of the number of in-tolerance parts produced from a given alloy relative to the number of in-tolerance produced from free machining brass (C36000 – CuZn37Pb) is the machinability rating for that material.

Note that the machinability rating is not an absolute number. Many factors influence machinability. Material will respond differently to different machining operations.

#### Input Rod or Wire Material

- Temper and hardness
- Surface finish
- Straightness
- Residual stress
- Grain size
- Lead content
- Toughness and ductility

#### Machine

- Individual machine
- Tool material type, hardness, shape, sharpness and wear
- Feeds, speeds, and depth of cut
- Operator skill
- Lubricant/coolant type, cleanliness and amount
- Rod/wire centering on lathe
- Fixturing/chucking
- Amount of vibration

#### Final Part Configuration

- Shape and size
- Dimensional tolerance requirements
- Surface finish requirements
- Amount of material removed
- Required heat treatment and potential distortion

#### Particular Machining Operation

- Turning
- Drilling
- Sawing
- etc.

## ROD AND WIRE ALLOYS

Materion produces Alloy 25 (high strength copper beryllium) and Alloy 3 (high conductivity copper beryllium) rod and wire. In addition, ToughMet® 3 rod or wire is a high strength, spinodally hardened copper nickel tin alloy, with strength approaching that of Alloy 25.

Lead (Pb) is often added to copper-based rod alloys to enable them to machine more easily in automatic screw machining operations. The Pb is not soluble in the copper, so it remains in discrete particles. The soft Pb functions as a chip breaker, to keep the machining chips short. It may also function as a solid lubricant, which helps to keep the tooling sharp.

Alloy M25 is a high strength copper beryllium alloy (C17300) developed specifically for automatic screw machine operations. The alloy's composition and mechanical properties are the same as those for Alloy 25 with the addition of 0.3% lead (Pb).

Brush® 1915 alloy is a heat treatable leaded copper alloy specifically designed for screw machining and cold heading applications. Its mechanical and electrical properties are similar to those of Alloy 3. Brush 1915 alloy is available in rod or wire in diameters ranging from 0.050 inch (1.27 mm) to 0.500 inch (12.7 mm).

Note that Alloy M25 (0.3% Pb) and Brush 1915 alloy (0.8% Pb) are both fully RoHS compliant. The RoHS directive allows up to 4% Pb to be added to copper alloys to improve machinability. Note that only 0.3% Pb is required to improve the machinability of high strength CuBe from 20% to 50% relative to free cutting brass.

**Table 1.—Materion Rod & Wire Alloys**

Alloy	Yield Strength Range	Electrical Conductivity (%IACS)	Machinability Rating vs. Free Cutting Brass
25	145-220 ksi 890-1520 MPa	22-28	20%
M25	145-220 ksi 890-1520 MPa	22-28	50%
3	80-125 ksi 550-870 MPa	45-60	40%
Brush 1915	25-100 ksi 170-690 MPa	48	70%
ToughMet 3 rod/wire	90-210 ksi 620-1450 MPa	7	20% (estimated)

## WIRE AVAILABILITY

Materion supplies cold drawn wire in coil form on spools or reels. Materion produces this wire with tolerances according to ASTM B250, Table 2 (for diameter/roundness only). Wire is supplied annealed (A), quarter hard (1/4H), half hard (1/2H), or full hard (H) tempers. In special cases, prehardened (also called "pretempered") wire is available. This product offers versatility in strength and durability for products with mild to somewhat stringent forming requirements.



Wire is available in diameters ranging from 0.030" to 0.5" (0.76 mm to 12.7 mm) for A, 1/4 H, and 1/2 H tempers. 3/4 H, and H tempers are available in 0.030" to 0.080" (0.76 mm to 2.0 mm) diameters. Finer diameter wire may be supplied by any one of a number of wire redrawers – contact Materion for availability.

## ROD AVAILABILITY



Wire that is straightened and cut to length is called rod, although only the tempers recognized by ASTM are standard product. Copper beryllium rods are available in the as annealed (A), cold drawn (H), annealed and precipitation hardened (AT), and annealed, cold drawn and precipitation hardened (HT) tempers. Other tempers not recognized by ASTM (such as 1/4 H and or 1/2 H) can be custom fabricated on request, but the customer must clearly define the expected properties at the time of order.

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Materion supplies rod in straight lengths up to twelve feet (3.7 m), in diameters ranging from 0.030 inches to 2.5 inches (0.76 mm to 63.5 mm). It is available in either specific lengths or random mill lengths. It is typically provided in an annealed or cold drawn temper and heat treated after machining.

The precipitation hardened tempers (AT, HT) of copper beryllium are available only in diameters of 0.4375 inches (12.0 mm) or greater. Smaller diameter rod cannot be heat treated and still maintain straightness. Rod smaller than this diameter must be purchased in the heat treatable tempers, and then heat treated after machining.

For automatic screw machining processes, rod may be purchased with pointed and/or chamfered ends for easier feeding into screw machines and easier grasping by the chucks or collets in such machines.

Note that in Alloys 25 and 165, the material will shrink during age hardening. Linear dimensions will decrease by about 0.2%, and there is potential for distortion. If exceptionally tight tolerances are required, it is best to rough machine, heat treat, and then finish machine to final dimensions.

## ROD STRAIGHTNESS AND SHAPE

ASTM B249 specifies the tolerances for rod (Table 2 for diameter/roundness, Table 15 for lengths, and Table 16 for straightness). Rod straightness is measured by laying the rod horizontally in contact with a straightedge, and measuring the maximum deviation from edge of the straightedge. Please be aware that straightness measurements may be problematic for small amounts of curvature, as it is difficult to tell whether the deviation from straightness comes from curvature of the central rod, eccentricity of the cross section, or deviations in diameter.

Centerless grinding may be used to improve the shape tolerance and straightness. However, this would require starting with an oversize rod, which would increase the price of the rod due to extra processing and scrap loss.

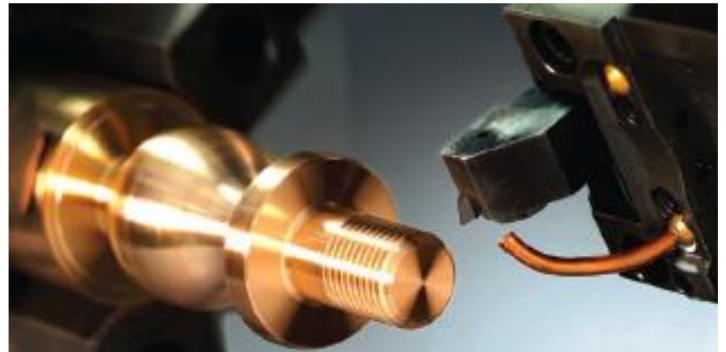
## MACHINING OPERATIONS

Machining is really controlled fracture of the material. Brittle or weak materials that are easy to fracture will machine readily. Conversely, materials that are very strong, ductile, or tough will be difficult to machine. So, the characteristics that make a material work well in applications requiring strength and toughness will result in poor machinability. Materials that are very easy to machine will probably not work well in such applications.

Cutting tools should be sharp and have a positive rake angle between 5 and 20 degrees for best performance (greater than 15 degrees for ToughMet® 3 rod). The use of chip breakers for chip control during turning is recommended.

Materion strongly recommends the use of a cutting fluid as a coolant and for chip removal for longer tool life and improved surface finish. Water soluble oils and synthetic emulsions are commonly used coolants. Although the best finishes are obtained from sulfurized oils, these oils will discolor copper beryllium and copper nickel tin (as well as other copper alloys). The stain is not harmful, but oil should be removed after machining, particularly if the parts will be subsequently age hardened.

Cutting metal requires a significant amount of energy, which results in heating of the chips and cut surface. This temperature rise can damage the cutting surface of the tool and lead to high residual stress in the workpiece, unless it is carried away by conduction through the metal or by flooding with coolant. ToughMet 3 rod in particular has lower conductivity than the other materials, so it requires flooding with copious amounts of cutting lubricant to cool the cutting zone.



Most automatic screw machines require relatively straight rod to be fed in. The rod would be held in place and spun by chucks or collets held on each end of the rod.

Escomatic screw machines (manufactured by Esco SA in Switzerland) are able to take coiled wire as input stock, due to an integrated straightener in the feed section. This allows for greater throughput and less scrap compared to machines that feed one rod at a time.

High metal removal rates sometimes present chip removal problems with cold worked or annealed products, particularly those without lead content. Long, stringy, tough chips are difficult to handle. To avoid this difficulty, non-leaded copper beryllium is usually machined in the age hardened (AT or HT) condition. In addition to improved chip

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control, age hardening and cleaning after machining are eliminated.

As with many high performance alloys, machining can work harden the surface of a copper beryllium or copper nickel tin workpiece. Shallow depth of cut or a dull or rubbing tool can accentuate this hardening. For best results, be sure that the tool is sharp and that the feed rate is sufficiently high that each subsequent cut penetrates below the work hardened layer.

Consult Materion Technical Service for proper machining feeds, speeds, and tooling configurations. These may also be found in the publications "Machining Copper Beryllium" and "Machining Recommendations for ToughMet® Rod, Tube, and Plate", available on [materion.com](http://materion.com).

## RESIDUAL STRESS

The small diameter rod and wire that is machined into connectors usually starts in a much larger diameter round casting. This casting is extruded and drawn down to the required size through many operations. Since the material is elongated many times (up to several kilometers in some cases), it must be coiled onto spools for handling. The material may then be purchased on a spool as wire, or it may be straightened and then cut to length as a last step to be purchased as rod.

When the wire is coiled, it is usually in a relatively stress-free state. In order to make the coiled wire straight, it will need to be permanently deformed in a straightener, which will add some residual stress. The straightening process essentially removes wire curvature by elongating the concave side of the coil and shortening the convex side.

If the rod is insufficiently straightened, its curvature may make it difficult to feed into an automatic screw machine. Conversely, if the rod is overstraightened, then it will have excessive residual stresses, and it may also have another set of shape problems that prevent good feeding. If done properly, the rod will feed appropriately into the machine, with minimal residual stress.

Additionally, the straightening operation works by adding strains to balance residual stress around the outer circumference. This imparted strain is highest at the outside diameter of the rod, and is near zero at the central axis. Material near the center of the rod or wire is relatively unaffected by the straightening operation, and may still have inherent curvature. As a greater amount of cross section is machined away, the more the parts will want to return to their natural curvature.

## MACHINING DISTORTION

As tooling wears, the machining process itself will introduce a greater amount of residual stress into the machined parts. This residual stress can cause the parts to distort out of tolerance. With larger parts, there will likely be a lot of material to stiffen the parts and resist movement. With smaller connectors, there is less material to resist this movement. As parts get longer and thinner, the tendency to distort increases.

With many free machining materials, the operators will change the tooling when the parts coming off the machine are out of tolerance. However, when machining Alloy 25, Alloy 3, Brush 1915 alloy, or ToughMet 3 rod or wire, the residual stress from machining may reach problematic levels while the produced parts are still within geometric tolerances. So while the parts come off the machine in tolerance, any subsequent machining or heat treating operation could create distortion, due to residual stress.

If you are sawing tines in the material to make a slotted cylindrical connector, you are breaking the continuity of the outside diameter, and any subsequently unbalanced residual stress may cause the tines to move. Again, this is effect is greater with longer and/or thinner tines than it is in shorter and/or thicker tines.

For a solid circular section with a diameter of  $D$  and a residual stress of  $\sigma_r$ , the deviation from straightness would be:  $d = \frac{2 \cdot L^2}{3 \cdot E \cdot D} \sigma_r$ , where  $E$  is the elastic modulus and  $L$  is the length of the section. On an individual tine of thickness  $t$ , the equation becomes:  $d = \frac{2 \cdot L^2}{3 \cdot E \cdot t} \sigma_r$ . In either case, doubling the length means quadrupling the distortion for a given amount of residual stress. Another way of looking at the problem is that when you double the length, you only need  $\frac{1}{4}$  as much residual stress to cause unacceptable distortion.

## PART GEOMETRY

Most operators machining parts from rod or wire would start by turning the outside diameter on a lathe or automatic screw machine. For slotted cylindrical contacts, they would then drill or bore the inside diameter, and then saw or EDM the slots to make the tines. Usually the other end of the contact would be crimped onto a wire in a cable, which may require that the crimp end be zone annealed after finish machining.

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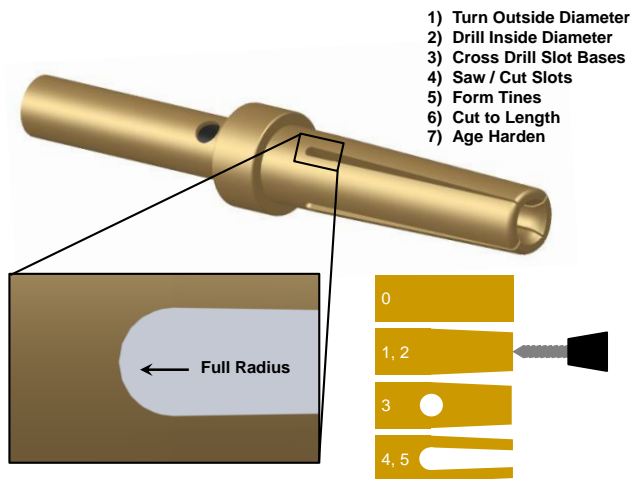
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**Figure 2. Recommended order for machining slotted cylindrical contacts. Step 3 may be skipped, but ragged sawn edges could function as stress risers that lead to later fatigue failures.**

If you are sawing to make the tines, use as much of a full radius as possible at the base of the slots, in order to avoid cracking and excessive stress concentration at the base of the tines. (The tines function as cantilever beams, and the base of the tines is where the stress is highest, so additional stress concentration there should be avoided.) It may help to drill a hole for the full radius at the slot base before machining the slots. (Figure 2). If tines open or close during slotting, it may be necessary to stress relieve before slotting. Even if the tines do not move during the slotting operation, enough residual machining stress may be present to cause the tines to distort during subsequent heat treatment. In this case, it is important to keep the tooling sharp to minimize residual stress formation. Furthermore, the part may be designed so that the slots close up to touch each other at the desired location during heat treatment, so that they support each other and prevent further distortion. However, if the tines open, or there needs to be some gap between the tines at the opening, fixturing may be necessary.

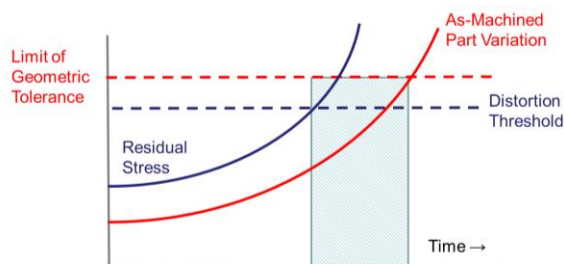
### ADDITIONAL CONSIDERATIONS FOR MACHINING TOUGHMET® 3 ROD OR WIRE

Note that some Materion publications relevant to the oil and gas industry describe the machinability of ToughMet 3 rod as excellent. This rating is in comparison to other materials commonly used in the oil and gas industry (such as high strength steels and nickel alloys), which are very difficult to machine. The machinability ratings of such alloys are usually compared to free machining steel (AISI/SAE 12L14) instead of free-cutting brass. So, while ToughMet 3 rod has greater than 100% machinability relative to free machining steel, it has only 20-30% machinability relative to free-cutting brass.

ToughMet 3 rod does not contain a phase like Pb that would contribute to short chip formation, so it is not a free-machining alloy. Its machinability falls between that of nickel alloys and brass/bronze alloys. (It is most comparable in machinability to manganese bronze.) ToughMet 3 material also has a tendency to work harden during machining, making each subsequent pass more difficult and contributing to tooling wear. As the tool wears, the residual stress under the surface of the cut also increases. This could lead to distortion during slotting or heat treatment.

ToughMet 3 rod or wire should be machined with a harder grade of carbide to minimize wear. Grade C5 is recommended for most applications. Chip breakers incorporated into the insert aid in producing a very short, manageable chip.

Additionally, spindally hardened copper nickel tin alloys like ToughMet 3 rod have excellent resistance to stress relaxation. While this improves the performance of connectors, it also means that the raw material does not thermally stress relieve, so it is important not to add as little additional residual stress as possible.



**Figure 3. Parts coming off the machine may still be within geometric tolerances, but the residual stress may be high enough to cause problems in future operations.**

As the tooling wears, a greater amount of residual stress is added to the parts, and the geometric variation would gradually drift out of tolerance. Depending on the part geometry, there will be a level of residual stress that will be sufficient to cause the parts to move out of tolerance during downstream machining or heat treating processes. Machine operators will usually change the tooling when it has worn to the point of producing out of tolerance parts. However, the residual stress builds faster than the geometric variation. The amount of residual stress that would cause distortion problems in downstream operations would happen well before there was any indication of out of tolerance parts. The parts to the left of the shaded area would process properly, and the parts to the right of the shaded area would be out of tolerance coming off the machine. However, the parts that are produced in the shaded area would be within geometric tolerances coming off the machine, but the residual stresses would cause

distortion later during subsequent machining or heat treatment operations. It is important to change the tooling before there are any noticeable out of tolerance parts.

To minimize residual machining stress:

- Keep the tooling sharp (change it more frequently than you normally would.)
- Flood with coolant, as thermal expansion in the tool can leave parts out of tolerance.
- Use positive rake angles (>15° is essential)
- Material work hardens – cut deep enough with each pass to get under the work hardened layer
- Use diminishing cuts (50% less per pass) minimize the size of the highly stressed work hardened zone at the end of machining.
- Contact Materion for additional special considerations for machining ToughMet® 3 rod.

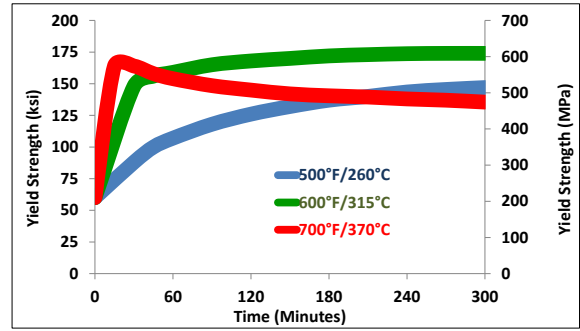
## DEGREASING

After machining, you will need to degrease the material before heat treating, plating, etc. to remove any residual rolling or stamping oil on the surface. You may use high pressure water spray around 50°C or 125°F, with or without soap. Trisodium phosphate and similar alkaline solutions also work well. (Use with ultrasonic agitation for best results) Vapor degreasing is also very effective on these materials.

Degrease before heat treating to ensure that there is no baked-on lubricant, which can cause problems in cleaning before plating, the plating process itself, or increase contact resistance in bare contacts.

## HEAT TREATING

Alloy 25 and M25 are typically age hardened after machining. Materion strongly recommends using recirculating air furnaces with controlled atmospheres for heat treating these alloys. The best option is a reducing atmosphere consisting of about 95% N<sub>2</sub> and 5% H<sub>2</sub>. Keep the dew point below -40°C (-40°F) and the O<sub>2</sub> level below 15 ppm to ensure very low moisture and/or oxygen in the furnace. Alternatively, pure N<sub>2</sub>, H<sub>2</sub>, or other inert gas may also be used. Try to keep the temperature within ±10°C (±15°F) of nominal for best results. To prevent excessive oxidation, let the parts cool in the furnace to around 65°C (150°F) or lower before removing them.



### Higher Temperature

- Short time required
- Lower peak strength
- Hard to control exposure time, quick to overage

### Lower Temperature

- Longer time required
- Higher peak strength
- Easier to control

Figure 4. Heat treating at 600°F/315°C is optimum for Alloy 25. The material reaches peak strength in just 2 to 3 hours, and provides a significant margin of error if the material is left in the furnace too long. (It is difficult to overage and soften the material at this temperature.) Note that the lines on the chart are deliberately made thick as a reminder to expect normal variation in properties.

## DISTORTION DURING HEAT TREATMENT

The material may require slight coining of the tines to achieve a repeatable and predictable movement during heat treat. Sometimes, even just inserting each parts into a fixture and then removing them before heat treatment may generate sufficient residual stresses in the appropriate direction that no further fixturing is needed during heat treatment. Be aware, however, that excessive coining may cause cracking.

One method to combat residual stress would be to thermally stress relieve the material. In slotted cylindrical contacts, the tines may sometimes move inward during heat treatment. This is usually not an issue, since this improves retention force, unless the tines are so close together that it prevents pin entry. If tines do happen to close too much during heat treatment, dummy steel pins of the same size as the desired gap among the tines may be inserted prior to heat treat cycle. The pins will allow the tines to close up to the desired distance apart, and no closer.

If the tines open outward during heat treatment, this is usually much more severe, as this would generally result in no spring force (and no electrical contact) during mating. In this case, a dummy steel cap may be placed over the end of the tines to keep them within the proper diameter. For extra control, you can use a cap with an integrated pin to completely prevent the tines from moving.

If the tines open outward, then a sleeve of some kind of inexpensive material may be placed on the end to fixture the parts during heat treatment. If the tines close, and a

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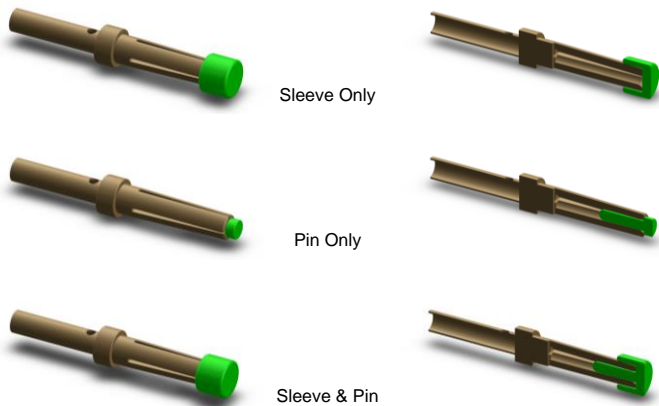
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minimum gap is required, then a pin may be inserted between the tines. If the movement is unpredictable, and neither opening nor closing is allowed, a combination sleeve with an internal pin would be used (Figure 5).

In a worst case scenario, the parts could rough machined, heat treated to full strength, and then finish machined. It should be noted that ToughMet® 3 rod, being very resistant to stress relaxation, will not respond to fixturing during heat treatment as well as M25.



**Figure 5.** If the tines open outward, then a sleeve of some kind of inexpensive material may be placed on the end to fixture the parts during heat treatment. If the tines close, and a minimum gap is required, then a pin may be inserted between the tines. If the movement is unpredictable, and neither opening nor closing is allowed, a combination sleeve with an internal pin would be used. Sometimes, even just inserting each part into a fixture to coin it and then removing the part from the fixture before heat treatment may generate sufficient residual stresses in the appropriate direction that no movement in the wrong direction occurs. This means that the parts can be heat treated without additional fixtures.

## MITIGATING HEAT TREAT DISTORTION

Machining and/or forming operations impart residual stress to the contact. During age hardening, unbalanced residual stresses can cause the parts to distort (e.g. tines open or close) It is usually beneficial if the tines close up, as long as the mating pin can still easily fit among the tines. This will also increase normal force and retention force. The key would be to ensure consistent part to part residual stress, so that distortion is consistent and in the proper direction. To prevent distortion on upon age hardening (or upon slotting the barrel):

- Keep the turning tools sharp to minimize residual stress imparted to the outside diameter of the tines.
- Use sharp drill to minimize residual stress imparted to the inside diameter of the tines.
- Drill the hole beyond the expected base of tines
- If distortion still causes parts to be out of tolerance, fixturing may be necessary during heat treatment (Figure 5)

## CLEANING AND OXIDE REMOVAL

During aging, the copper beryllium alloys develop a surface oxide composed of beryllium oxide and, depending on the alloy and furnace atmosphere, copper oxides. These oxide films vary in thickness and composition and are often transparent. After a typical age hardening heat treatment in an “inert” atmosphere, expect a film thickness of about 0.03  $\mu\text{m}$  (1.2  $\mu\text{-inches}$  or 300 angstroms) on Alloy C17200. Under solution annealing conditions the film can reach as much as 0.3-1.3  $\mu\text{m}$  (12-50  $\mu\text{-inches}$  or 1000-1200 angstroms).

Connector manufacturers frequently age harden the copper beryllium after stamping and must clean the parts before subsequent processing. There are many acid combinations which can be used, but those proven most successful in removing films containing beryllium oxide are sulfuric/peroxide (20%  $\text{H}_2\text{SO}_4$ , 3%  $\text{H}_2\text{O}_2$  at 52°C [125°F]) and phosphoric/nitric/acetic (PNA) (38%  $\text{H}_3\text{PO}_4$ , 2%  $\text{HNO}_3$ , 60%  $\text{C}_2\text{H}_4\text{O}_2$  at 71°C [160°F]). Nitric acid alone does not do an adequate job of removing beryllium oxide films unless these films are pretreated in hot, concentrated sodium hydroxide caustic (50 - 60%  $\text{NaOH}$  at 129°C [265°F]). The sulfuric/peroxide solution is also effective on ToughMet 3 rod or wire.

Following is a note of caution when dealing with any copper alloy containing lead, such as Alloy M25 (C17300). Use nitric acid or PNA rather than a sulfuric acid system because of the insolubility of lead sulfate. Following alkaline cleaning, a preplating acid dip for leaded alloys is fluoroboric acid (10-25% at room temperature). A cyanide copper strike is a cleaning and activating step essential for plating leaded alloys.

If you are ultrasonic cleaning after heat treatment, be careful that you do not cause fatigue failures by driving the ultrasonic bath at a natural resonant frequency of the machined parts.

## CRIMPING

The keys to getting a proper crimp around a wire with machined contacts are the same as those for stamped contacts. Namely, you want to minimize the wire crimp diameter and maximize the wire deformation. This increases contact force and encourages localized cold welding between the wire strands and the crimp barrel, which will help increase the tensile pullout strength and minimize the contact resistance of the crimp interface. It is also important to minimize the void space between wire strands and to avoid fracturing any wires, to keep corrosive agents out of the crimp zone.

You should also keep the tooling sharp by replacing the punches and anvils frequently. If you are having difficulty

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with getting a good crimp, you may have to zone anneal the crimp barrel first.

## ZONE ANNEALING

When the material is at full strength and hardness for maximum spring properties, it will likely not be ductile enough to survive a crimping operation without cracking. Therefore, the end that is to be crimped must be thermally softened to provide it with the required ductility. CuBe may be overaged to soften it, or it may be solution annealed and quenched. The ductility of ToughMet® 3 parts decreases before it increases when they are overaged, so contact Materion Performance Alloys Technical Service for guidance on appropriate zone annealing parameters.

Overaging or solution annealing is best accomplished by induction heating. This allows precise control of time and temperature in the crimped end, and minimizes the heat affected zone next to the softened end. Sometimes the softening may be done with an open flame, but this is not recommended, as it will be extremely difficult to consistently control the time and temperature.

Care must be taken to keep the temperature below the melting temperature of any phases in the base metal, or there will be some incipient melting, particularly at the grain boundaries. Any zones that are melted and resolidified will not have the optimal microstructure, and may be inherent weak points in the parts.

In zone annealing you are locally heating the metal to the point where it becomes soft enough to crimp. You can either greatly overage the material to increase the ductility (with some loss of strength and hardness) or you can provide a true solution anneal (which recrystallizes the microstructure and eliminates the strengthening achieved by prior cold work and age hardening).

You must heat M25 to greater than 800°F (425°C) for overaging. Water quenching is not necessary, but may help to keep the heat affected zone from spreading too far into the spring area of the contact. ToughMet 3 and Alloy 3 rod or wire require much higher temperatures to improve ductility. Contact Materion Technical Service for guidance.

To get a true solution anneal, you must heat above the solution annealing temperature, but below the solidus temperature to prevent incipient melting of the metal. Contact Materion Technical Service for the appropriate solution annealing temperatures and procedures for your material.

Most zone annealing is done by induction heating or flame heating. In flame heating, it is difficult to precisely control

temperature and duration, and may result in some deleterious phases forming in the material that would be avoided in normal processing.

Induction heating is very rapid, with little time for heat to conduct away from zone. However, it is easy to overheat and melt the grain boundaries. Please consult your induction heating equipment supplier for proper setup.

## HEALTH AND SAFETY

Copper beryllium (CuBe), in solid form and as contained in finished products, presents no special health risks. Most manufacturing operations conducted properly on well-maintained equipment are capable of safely processing copper beryllium containing materials. However, like many industrial materials, copper beryllium may present a health risk if handled improperly. The inhalation of dust, mist or fume containing beryllium can cause a serious lung condition in some individuals. The degree of hazard varies, depending on the form of the product, how it is processed and handled, as well as the amount of beryllium in the product. Read the product specific Safety Data Sheet (SDS) for additional environmental, health, and safety information before working with copper beryllium alloys.

## REFERENCES

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