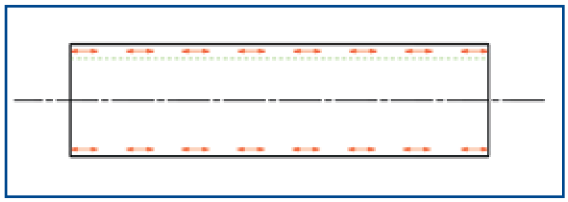
Taking the Stress Out Of EDM

The combination of the lack of awareness of and compensation for EDM workpiece stress can ruin just about any EDMer's day. This article will attempt to identify common causes of stress in EDM workpieces and propose strategies to minimize the negative effects of residual or induced stress on finished workpiece quality.

Most all workpieces contain residual stress. Just because a blank is flat, parallel, and square within .0001 does not mean that it is stress free. ***(See Fig #1)***. It merely means that the stresses in the work piece are balanced, equal, and opposite-for the moment. Even if the work piece does not contain residual stress, our method of holding the work piece in the machine can often induce stresses that can cause problems either during machining or after the part is unclamped.



FLAT BLOCK WITH BALANCED RESIDUAL STRESS BEFORE STOCK REMOVAL TO GREEN DOTTED LINE

Fig. #1

The slug shown in ***Fig #2*** was Wire EDMd from a transfer press cam which had many years of cold work stress induced on the inner roller follower track. Note the amount of deflection caused by the release of the cold work stress.

Fig. #2

EDM is often wrongly accused of causing workpiece distortion and occasional cracking by adding stress to the part. Most always, except for very high power sinker burns, this is not the case.

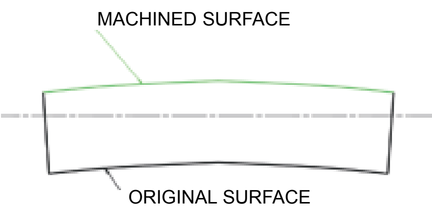
Have you experienced any of the following circumstances?

- I checked the part for flatness before EDM and now it is bowed .002".
- My skims did not clean up even though I left the recommended allowance.
- I set up the part for a weekend burn and returned to find the wire shorted in the slot and a crack radiating from the burn to the edge of the block.
- There are cracks and spalling in my carbide punches.
- My cased carbide die cracked during the roughing burn.
- There is a contour mis-match at my cavity start-end.
- The gear opening I roughed and skimmed in the die bushing is out-of-round by .001".

These are all instances of EDM relieving stress that was a pre-existing condition in the EDM work piece or induced into the work piece by clamping!

A well known example of machining releasing residual stress is that of the apprentice milling only one side of a piece of cold rolled material to bring it to finish dimension. ***(See Fig #3)***

Let's examine some of the more common causes of stress that can result in unsuccessful EDM outcomes.



WARPED BLOCK DUE TO UNBALANCED RESIDUAL STRESS AFTER STOCK REMOVED FROM TOP SURFACE

Fig. #3

Raw Material Stress

It is common practice for some EDMrs to Wire cut male or female electrodes from blanks of wrought Copper or Tellurium Copper. These materials are supplied by the mill as cold rolled material. As a result of the tremendous deformation that occurs as the bars are cold formed from the cast billet without benefit of stress relief, cold rolled Copper bars are loaded with residual stress, just like our cold rolled steel example. Cutting openings in or cutting out electrodes from cold rolled material will result in significant movement of the material during the cut.

To minimize the possibility of stress induced strain movement, use stress relieved Copper. Stress relieved Copper is subjected to a prolonged heating and slow cooling cycle which relieves the cold work stress.

Carbide is a material that is commonly EDMd. Carbide is a powder metal product produced by compacting and sintering a mixture of Tungsten Carbide and Cobalt powders. During the sintering process, the material shrinks by approximately 25%, which has the potential to induce a significant amount of residual stress. Cutting carbide by the EDM process, particularly by the Wire EDM process which progressively machines a contour by cutting a slot, can unevenly relieve the residual stress in a way that can cause the blank to crack.

The following strategies can be employed to reduce the possibility of stress related failure in carbide workpieces:

- Purchase carbide from reputable manufacturers who offer grades that are formulated and processed specifically for Wire EDM operations.
- Design relief cuts and openings into the pre-form to minimize sintering stress
- WEDM relief cuts and roughing cuts into the material before making any finish cuts.

Brazing Stress

Many tool blanks that are subsequently EDMd are a matrix of carbide and steel that are brazed together. During the brazing process, the carbide and steel are heated to a temperature exceeding the melting point of the brazing material (usually silver solder). Unfortunately, the coefficient of thermal expansion for carbide is approximately one half that of steel, and when the brazed assembly cools to room temperature this differential in the shrinkage of the two materials induces significant residual stresses which can bedevil subsequent EDM operations.

Most knowledgeable brazing specialists place a copper shim in between the carbide and the steel which will help absorb some of the differential shrinkage. Also, if possible, braze a number of shorter pieces of carbide to the steel, rather than one long piece. The gaps will provide a natural stress relief point.

In addition, you should follow the same strategies for stress relief as previously mentioned for carbide.

Manufacturing Stress

The only manufacturing processes that do not induce stress onto the surface of a part are lapping and honing.

- Milling and turning processes add cold work and heat stresses to the surface of a part which may be either tensile or compressive.
- Grinding, the resulting sparks of which indicate very high induced temperatures at the part surface, usually imparts residual tensile stresses to the surface of a part.

Thus, it is possible that the nicely machined or ground blank furnished for your subsequent EDM operations might easily be loaded with residual stress just waiting to unwind in your machine.

Heat Treating Stress

The heat treatment of materials can cause significant residual stress by two different mechanisms.

For the majority of steel parts, the heat treating cycle causes a change in molecular structure from a face center cubic crystal structure of Austenite to the body center tetragonal crystal structure of Martensite. This change in molecular structure results in a very slight expansion of the material which often leads to residual stress, much of which is usually relieved during the tempering process. However, during quenching, not all of the Austenite is converted to Martensite, leaving perhaps 2-3% of unconverted material which will eventually convert at some time in the future. This subsequent conversion will result in additional unrelieved residual stress.

The are two strategies to combat this situation for critical parts:

Use air hardening steels whenever possible. An air quench is less severe than an oil quench and usually results in less residual stress.

- Utilize a deep freeze and double draw process subsequent to the normal heat treating process. Deep freeze and double draw consists of bringing the part down to 100 degrees below zero to convert any retained Austenite and then double tempering the part to relieve any residual stresses. My shop successfully employed this technique in manufacturing Wire EDM'd root form gages for aircraft engine rotors, holding total form tolerances as tight as +/- fifty millionths.

Some materials, such as aluminum, titanium, and certain stainless steels are heat treated in just the opposite manner. They are quenched to solution treat the alloy and then age (precipitation) hardened. Some of these alloys will continue to harden at room temperature. Age hardened materials can be subject to residual stress. The only practical strategy for this group of materials is leaving substantial allowances after roughing cuts.

Shrink Fit Stress

Carbide, like concrete, has high wear resistance and compressive strength but has low tensile strength. To combat this shortcoming in many metalworking applications (such as draw dies, extrusion dies, and powdered metal compacting dies) carbide inserts are often inserted in steel cases. The carbide is retained in the steel case by means of a significant interference shrink fit which imparts a substantial residual compressive stress on the carbide insert which helps it resist the tensile stresses resulting from drawing, compacting, or extrusion operations. This interference fit is often in the neighborhood of a least .001” per inch of the carbide insert diameter. Thus, the carbide insert is under very considerable residual stress imparted by the steel when we begin our EDM operations on it. As the EDM operation proceeds, it not only removes material that was resisting the shrink fit stress but often does not remove it evenly from the carbide cross section. The result is often a cracked insert.

The strategy for dealing with shrink fit stress in cased carbide draw, extrusion or compacting dies is often a combination of:

- Choosing a carbide grade suitable for casing and EDM.
- Roughing out the interior form in the carbide pre-form prior to sintering.
- Roughing out the interior form in the carbide pre-form prior to casing.
- Providing generous internal corner radii for internal shapes.
- Taking numerous roughing passes to ease the transition from the pre-form to finished geometry followed up with multiple skims.

It should be noted that burning interior shapes into cased carbide dies by Sinker EDM can substantially reduce the cracking risk since the entire shape is burned into the part simultaneously rather than being generated progressively by burning a slot in the Wire EDM. The risk is also lowered by the fact that the shape is progressively sunk in the Z-Axis direction as opposed to immediately introducing a stress relieving slot through the entire part thickness.

Press Fit Stress

The effects of Press Fit Stress are similar to those of Shrink Fit Stress, except that the amount of interference and related residual stress is substantially lower. However, when working to “tenth” tolerances, any level of residual stress needs to be addressed to assure a successful result. The strategies for Press Fit Stress are similar to those listed above for Shrink Fit Stress.

Clamping Stress

The foregoing itemized stresses are conditions that accompany the common materials and processes leading up to the EDMing of the part and can be successfully dealt with utilizing the strategies proposed. However, there is another list of avoidable stresses that are often the consequence of setting up and holding the part in the EDM that we now need to consider.

The two most common methods of presenting a part to the Wire EDM with standardized tooling systems are the vise and the vee block, as these methods allow unfettered access by the lower flush cup to the bottom of the work piece without fear of collision. Unfortunately, in order to resist the substantial forces on the work piece imparted by today’s high pressure flushing, these devices need to grip the work piece quite securely and therein lies the potential problem. Let’s examine each piece of tooling individually.

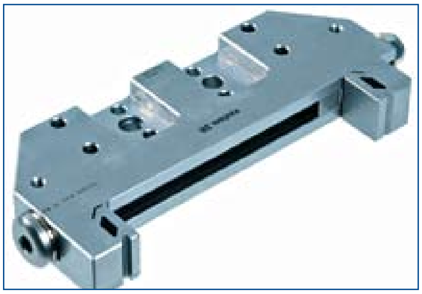


Fig. #4 (photo courtesy of system 3R)

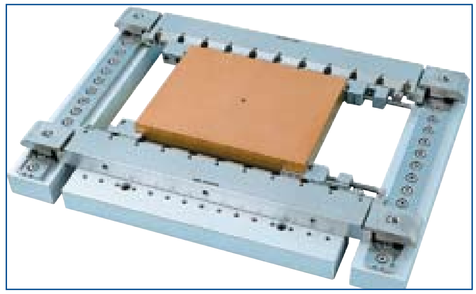


Fig. #6 (photo courtesy of system 3R)

Fig. #7 (photo courtesy of system 3R)

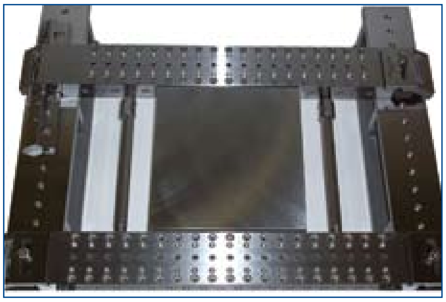


Fig. #5 (photo courtesy of Gaiser EDM Tooling)

The EDM Vise

There are two types of EDM vises: The most common vise design ***(See Fig #4)*** grips the edge of the part, depending on friction resulting from the squeezing force to prevent the part from moving as a result of gravity and flushing forces. In order to resist these rather significant forces, since the friction force is only a fraction of the squeezing force, a rather large squeezing force is required resulting in the potential for substantial localized stress on the part.

Another style vise design ***(See Fig #5)*** grips the entire width of the part, again depending on friction resulting from the squeezing force to prevent the part from moving as a result of gravity and flushing forces. The advantages of this type of vise is that squeezing force is often lower than that of the edge gripping vise since it does not have to resist the twisting moment of gravity and flushing forces and that the stress from the squeezing force is spread out over the entire width of the part rather than being localized on just one end.

A vise can induce substantial stress within a work piece resulting in significant form errors when the work piece is unclamped.

The following strategies can minimize stress related problems in vises:

- Use the minimum necessary clamping force. This is definitely a case where more is not automatically better.
- Carefully prepare blocks so that the clamping surfaces are ground parallel to evenly distribute the stress.
- When using edge type vises, consider using a pair to support the part at both ends. ***(See Fig #6)***
- Rough saw large openings.
- Rough all openings before any finish skims.
- Unclamp, re-grind, and re-clamp if a large amount of mass has been removed by roughing cuts.
- For punch blanks, leave a significant frame around the punch outline (at least 1/5 of the work-piece thickness).
- Consider the Clamp-Glue method (details to follow)

The EDM Vee Block

The EDM Vee Block ***(See Fig #7)*** is a wonderful device for holding round parts in the Wire EDM in that it not only holds the part free of lower arm

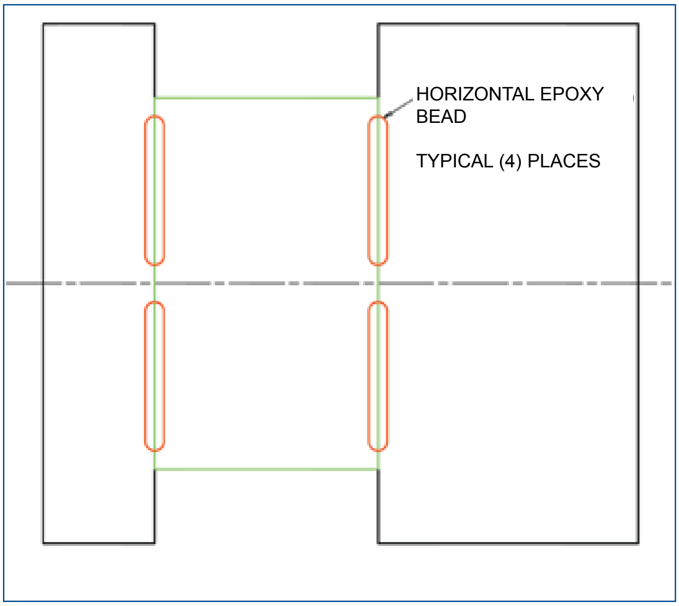


Fig. #8

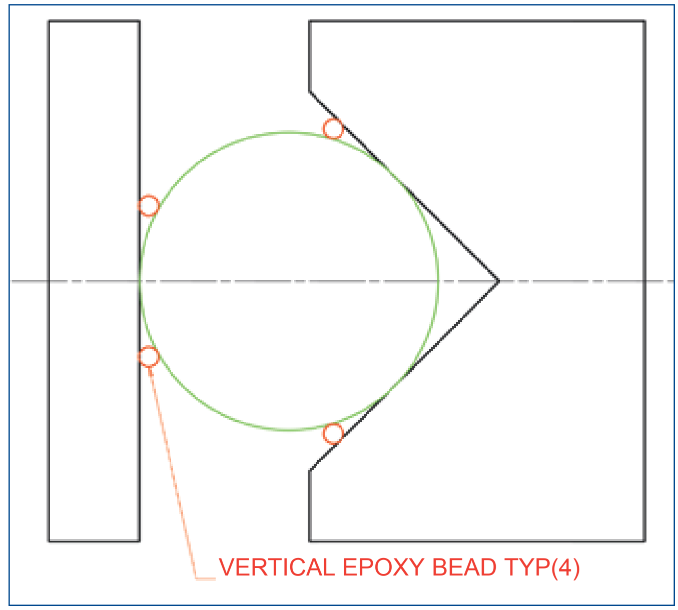


Fig. #9

constraints but it also provides repeatable location for parts and holds parts more securely because it envelops them. However, the EDM Vee Block, like its vise cousin, can generate significant stresses in the blank being EDM'd.

The primary problem with parts held in a vee block is that the clamping pressure forces the part out-of-round prior to or while the part is being EDMd. When the part is complete and the clamping forces relaxed, the part returns to its round state while the EDM geometry becomes distorted.

Got a great idea that you'd like to share with fellow EDM'ers?

Here's your chance to share your knowledge and earn some cash and notoriety at the same time!

— Here are the rules —

1. Email a description of your idea along with photo's, drawings, sketches, and your photo to: askroger@sbcglobal.net
2. Use the words ***"Reader Tip"*** in the heading of your email.
3. Include your name, company name, address and company phone number.
4. If we select your idea for publication, we'll send you **$100.00** as well as publish your photo and give you the recognition you deserve.

The following strategies can minimize stress related problems in vee blocks:

- Use the minimum necessary clamping force. This is definitely a case where more is not automatically better.
- Carefully prepare work pieces so that the clamping diameter is ground round and without taper to evenly distributethe stress.
- Rough saw large openings.
- Rough all openings before any finish skims.
- Unclamp, re-grind, and re-clamp if a large amount of mass has been removed by roughing cuts.
- For punch blanks, leave a significant frame around the punch outline (at least 1/5 of the work-piece thickness).
- Consider the Clamp-Glue method (details to follow).

The Clamp-Glue Method

So, one might ask, how do we get the convenience, versatility, safety, and repeatability of vice and vee block clamping systems without seemingly inevitable clamping stress?

The answer lies in a tube of Five Minute® (or equivalent) epoxy glue.

Just set up your part in the vise or vee block as you normally would on the pre-set station using only minimal clamping pressure. Just snug the clamping screw enough to prevent the part from sliding or spinning under hand pressure. Then, mix up the epoxy and lay a small bead along the top junction between the part and the vise jaws ***(See Fig #8)*** or along the line contact between the diameter and the vee and clamp ***(See Fig #9)***. Allow the epoxy to cure about five minutes, then mount the leveling head on the tooling rail. The contact between the part and the fixture will provide accurate location while the epoxy will resist the gravity and flushing forces without imparting any stress on the part. When the burn is complete, a sharp rap with a non-metallic hammer will free the part from the tooling.

Conclusion

The two key elements necessary to minimize your stress in the EDM department are:

- Recognizing the possibility of stress in your workpieces and clamping.
- Employing the appropriate strategies to deal with those possibilities before hitting the start button.

Happy Stress Free EDMing!

Roger Kern

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