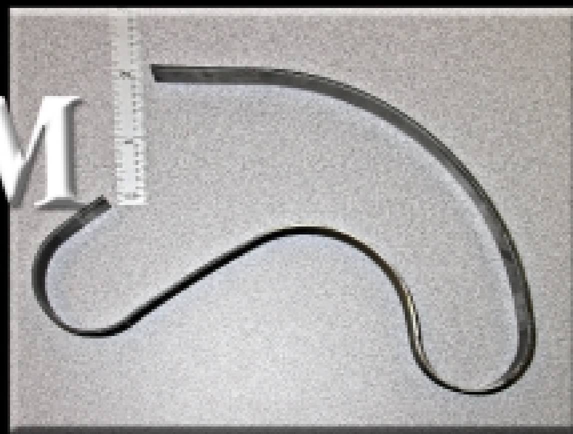
Quality & EDM



TechTips

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

by Roger Kern

— PART 1 —

"The parts we make ... can make an impact on someone's future." Whether it be Automotive, Aerospace, Medical, Oil Field, or even Toys, making things right and measuring them to verify that they're right are two critical aspects to any successful EDM operation. Talk about working to "tenths" is cheap, actually achieving and verifying "to the tenth" accuracy is very difficult. This next series of articles will explore both EDM process variability that contributes to workpiece geometry errors, as well as, measurement variability that degrades the certainty of verifying the quality of the parts that we EDM.

In this issue, we will explore the potential sources of variability in the Wire EDM manufacturing process with the goal of providing a better understanding of process limitations and, as a result, mitigating some of these variability factors to improve the quality of our work.

This list of contributing factors for variability in Wire EDM work is daunting, but should not be intimidating. In fact, some of these variability factors can cancel each other's effects. It is possible to accomplish very accurate EDM work on standard machines. I have seen aircraft engine root form gages (fir tree gages) with dozens of geometry elements Wire EDMed to a one tenth (.0001) total tolerance band (How that was verified will be the subject of part three of this series). However, to be fully informed of the possibility of process variance is to be forearmed.

Components of Variability in Wire EDM:

Machine Movements

Dielectric Bath:

Most machines today employ submerged cutting. The weight of the water in the work zone can be considerable. It is possible that unexpected movement of the machine structure will occur when the worktank is filled. This can cause position errors if the part was picked up with the worktank empty.

Roll, pitch, yaw:

The way system of any machine (this applies to X-Y, U-V, and Z axes) is subject to roll, pitch, and yaw errors. These deviations from perfectly straight and level travel are superimposed on all motions and can adversely affect results.

Travel squareness:

It is assumed that the X and Y (as well as U & V) axes are perpendicular to each other. Even a slight deviation from perpendicularity can affect the final product geometry, especially with larger dimensions. It is also assumed that the Z axis is perpendicular to the plane of the X & Y axes. Deviations here can affect the squareness of burned surfaces as well as taper angles.

Static positioning:

A machine's positioning accuracy is usually classified as a certain accuracy in a relatively small distance (say an inch) and an accuracy over the full length of axis travel for each axis. Therefore, it is usually easier to work to a tight tolerance within a small area of the machine's active travel as opposed to holding a "tenth" on a series of slots spanning 18". It is important to note that if we are "off' by a "tenth" in both X&Y, the resulting error is .00014".

Dynamic positioning:

When the machine is in motion, especially at higher speeds during skims, the actual dynamic position of the machine along the programmed path is determined by how well the servo gains of the individual axes are matched. Typically, dynamic accuracy is less than static accuracy. A typical example would be how well a machine follows the programmed path when executing a small radius at high speed.

It should be noted that machine manufacturers have made great strides in improving and controlling (often by laser compensation) these variability factors. However, it is unreasonable to expect that with the combination of these factors, most machines will be within a "tenth" anywhere in their travel, especially when in motion.

Temperature

Although the coefficient of linear expansion of steel is in the order of 6 millionths of an inch per inch per degree F, the potential for temperature variability in EDM is significant, primarily due to the fact that the machine structures are relatively large and therefore temperature movements of the machine can be significant. The following temperature issues need to be recognized for highly accurate Wire EDMing:

The environment surrounding the machine must be maintained at a constant temperature. While it would be preferable to maintain 68 deg F or 20 deg C (the international standard temperature for measurments), any temperature between 68 and 75 degrees is usually acceptable, as long as it is maintained 24/7. It should be noted that a sunbeam shining on the machine structure, or a cold or warm draft from the HVAC system blowing on the machine structure, can wreak havoc with machine stability. Proper venting of the power supply and chiller exhaust heat away from the machine location is also critical to machine stability.

The machine should not be turned on and off as jobs come and go. It can take as much as 12 hours for a machine to become thermally stable due to its internal heat sources.

The dielectric temperature should also be maintained within 2 degrees of ambient room temperature. In some machines, the high pressure flushing pumps draw from the temperature controlled clean tank, but add significant amounts of heat energy via the pumping process. This is especially true if the pump is left running with very little flow. The water subsequently supplied to the flushing nozzles can actually come out hot!

Guide System

For round guide machines, there is a certain amount of clearance built into the guide to allow for trouble-free threading. This clearance is often between .0002" to .0004", even on brand new guides. Thus, the wire may not be constrained from unintentional movement during cutting as much as we'd like to believe. The tendency of the wire to wander in the guide is significantly reduced by the pressure exerted by the offset power feed contact, holding it in one position in the guide. However, a worn and grooved power feed contact can affect the position that the wire sits in the guide. Obviously, a worn guide exacerbates this situation.

The upper and lower arms can be deflected by the significant forces exerted on them by the high pressure flushing system. This is primarily an issue with features generated by a single pass cut, located to a datum that was picked up when the high pressure flush was turned off.

EDM Wire

The standard tolerance for EDM wire is +0.000/-0.002 microns. Since EDM wire is manufactured by drawing it through a series of diamond draw dies, it is unlikely that the diameter of the wire within one spool will vary by more than a micron. Therefore, the net effect on the cut surface will be less than twenty millionths of an inch. Although it is often blamed, the EDM wire itself is seldom the cause of variation in the Wire EDM process.

Tapering

Tapering is a significant source of contour variability. The reason for this is that the wire (even a soft wire) does not precisely pivot at the exit of the guide. ***(See Figure 1)***. Since the trigonometric calculations in the machine computer for both taper angle and taper offset assume a crisp departure angle at the guide exit, both the contour size and taper angle may not be what is expected. This is especially true with larger taper angles.

Adding to this variability, for machines with round guides, the clearance between the wire and the guide will allow the wire to move to the wall in the direction of the taper as the taper direction changes in the course of the cut, thereby adding to contour variability.

For vee guide machines, the top of the 3rd point must be exactly in line with the end of the vee guide, or else the pivot point of the wire will change as the taper direction changes. Also, the mechanism connected to the 3rd point that maintains the pressure on the wire needs to be carefully adjusted, lest the wire be pulled slightly from the vee if the taper is in the direction that would tend to pull it out. Again, these effects are exaggerated by larger taper angles.

Needless-to-say, it is unlikely that tapered contours will be as accurate as straight contours.

Wire Squareness

The automatic squaring routines built into modern wire machines do a pretty good job of getting the wire square to the workplane of the machine (assuming the contacts on the squaring fixture are perfectly square to the base, and that the fixture is mounted properly to the machine tool table). However, when cutting a 1” punch holder that will locate a 3” long punch, even a .0001” per inch squareness error can result in unacceptable results when the punch-to-die clearance is only .0002” per side. On certain critical jobs, it may be necessary to skim two perpendicular edges of a block, and manually offset the U-V to obtain the required squareness.

Cutting Forces

During the course of the cut, the wire is subjected to numerous forces that can deflect it from the intended path:

Flushing forces:

Flushing pressures can be as high as 300 psi during rough cuts. This high pressure stream is blasted into the cut by the flushing nozzles. This flushing stream certainly has the capacity to deflect a .010” Diameter wire supported by a guide as much as 1” distant, especially with the continually changing geometry of the wire slot as the machine navigates complex geometry. Much of this effect can be removed by allowing for skimming after roughing.

Electro-magnetic Forces:

Many people wrongly believe that there is no force involved with EDM. In fact, repulsive discharge forces are generated during Wire EDM cutting. Since the forces are not symmetrical ***(See Fig #2)*** there is a net repulsive displacement force applied to the wire. The result is that the wire is no longer travelling in a straight line between the upper and lower guides ***(See Fig #3)***. Therefore the wire within the workpiece follows a different path than the wire as it exits/enters the guides. Thus, the wire is not where the machine control thinks it is. This situation is analogous to the different tracks that the front and rear tires of a car make when rounding a corner. Most machine controls have strategies

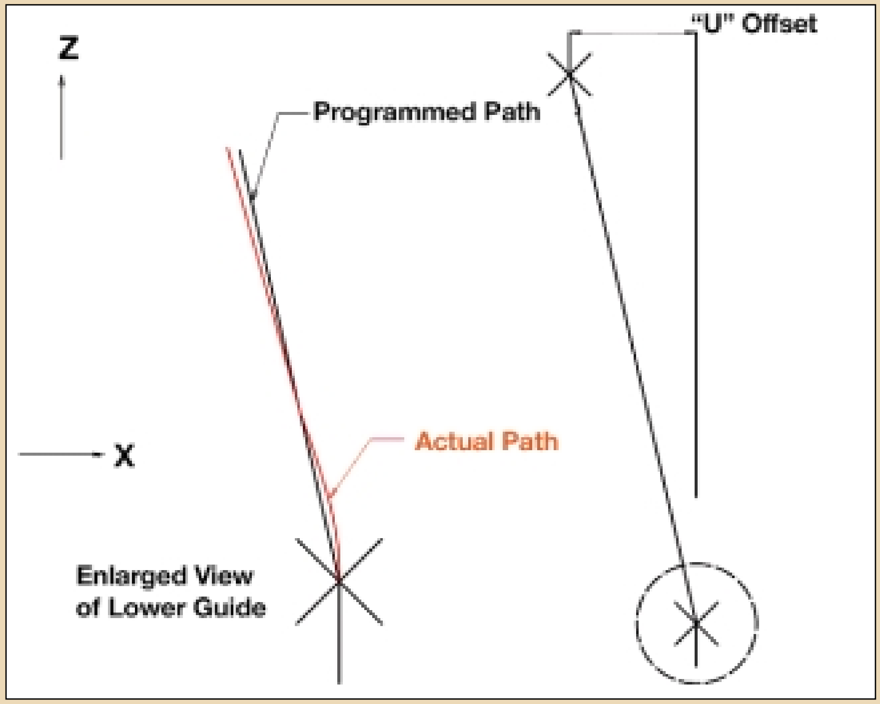


Figure #1

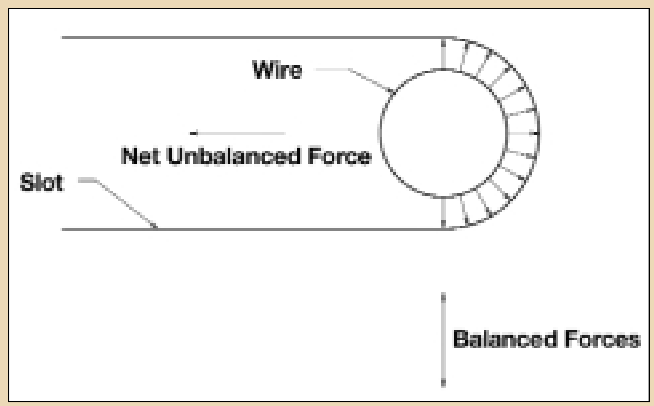


Figure #2

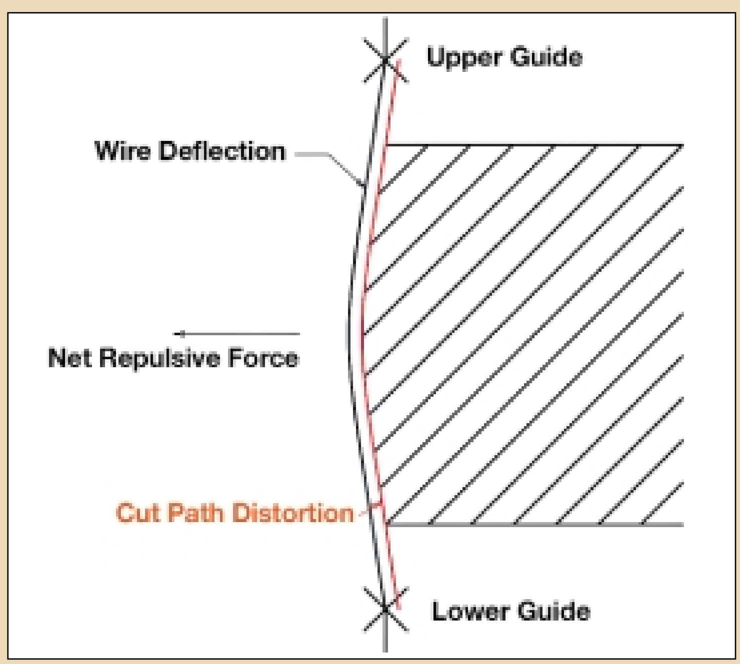


Figure #3

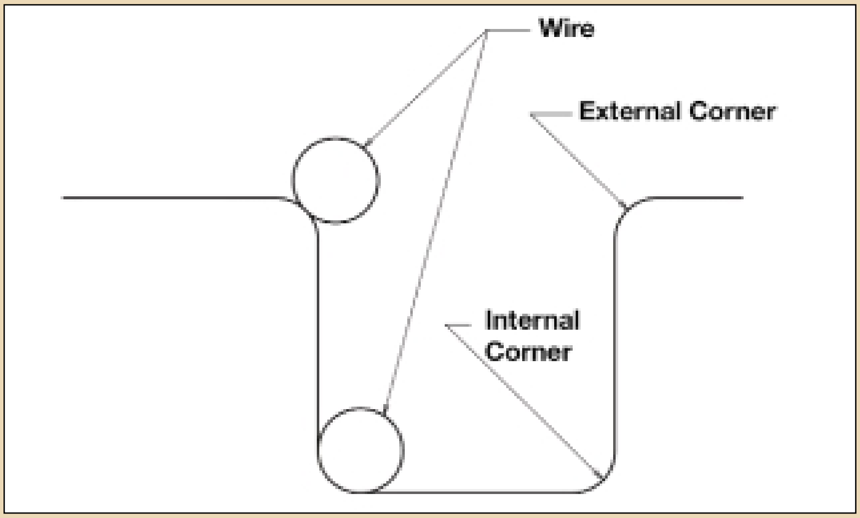


Figure #4

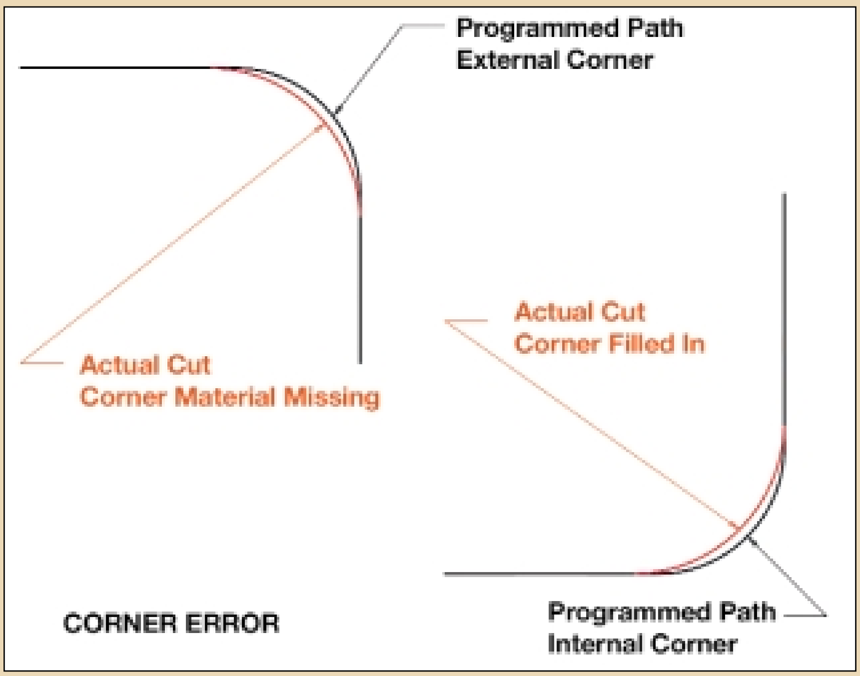


Figure #5

to deal with this effect, and as the current is reduced in skim passes, these forces become insignificant.

Bubble forces:

With each spark a gas bubble is created that encompasses the plasma of vaporized wire and workpiece material. When the spark energy ceases, this bubble collapses with considerable violence, expelling the eroded material. This continuous bombardment upon the wire of the collapsing bubbles can affect the position of the wire, either by displacement or vibration.

Corner Variability:

It is common knowledge that when milling a contour, the end mill will leave stock when machining an internal corner, and may take off too much stock when machining an external corner, due to the varying amounts of cutter engagement and corresponding pressure against the cutter, depending on the contour geometry conditions. This exact same phenomenon occurs with the Wire EDM ***(See Fig #4)***. Internal corners tend to be filled in and external corners tend to be lopped off. ***(See Fig #5)***. This condition is especially evident when trying to fit a tight clearance wire EDMed punch and die that have relatively sharp corners. This condition is exacerbated by small corner radii and small included corner angles. Taking multiple skim passes and allowing the wire to fully spark out on the final pass can substantially eliminate this condition.

Spark Gap Variability

There can be some variability of the predicted spark gap. This can be affected by dielectric cleanliness and conductivity, wire tension, generator condition, electricity supply voltage, and even workpiece material alloy content. While this variability is small and decreases with power settings, even one micron per side can alter a final overall dimension by a "tenth".

Set-up Variability

Blank Preparation:

If you are going to work to a "tenth" the Wire EDM blank must be parallel and square to within .0001"

Setup:

The blank must be held in the machine so that it is parallel to the reference plane of the machine, and square and parallel to the X & Y axes. Every "tenth" given up here is predictably added to the many variability factors we can't control.

Strain Movement

If the workpiece moves during the course of the cut, the accuracy of the job will be compromised. While a detailed discussion on strain movement will be the subject of a future article, let's briefly explore the two major causes:

Workpiece Instability:

There are a number of causes of workpiece instability:

- Residual stress within the material caused by a prior manufacturing process, such as cold working or sintering.
- Residual stress caused by the heat treatment or plating of the material.
- Residual stress caused by intentional pre-stressing, such as casing a piece

of carbide by a shrink fit.

- Insufficient mass of stock left around a punch to be cut.
- Excessive mass stock removed when a die opening is cut out from a block.

The general rule for the last two situations is that if you're removing much more than you're leaving, it's going to move.

Clamping Stresses:

Two common methods of holding a part are by pinching it in a vise or pinching it in a vee block. Either of these methods induces stress into the EDM blank that may get relieved when the blank is Wire EDMed and mass is removed. Unfortunately, the heavier the blank, the more the pinching force is applied, and the greater the risk of movement during cutting.

In all cases of workpiece instability, if the part moves during the cut after the wire went by, the contour will not be where you intended it to be.

Proper skimming process sequence can remove most of the movement errors if sufficient stock is left, and if sufficient skims are taken. In that regard, I have seen a 1" thick piece of 304 stainless move 3/16" over the course of an 8" cut. ***Fig #6*** shows the amount of movement that occurred when a highly stressed cam track was removed by wire EDM from a block.

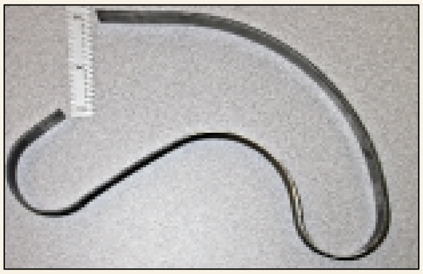


Figure #6

Post-EDM Processes

Bead Blasting:

Some shops bead blast parts after Wire EDM. While bead blasting does not remove metal, it does change the surface and in fact, can slightly alter size. This is especially true of external corners which have a high surface-to-volume ratio. For high tolerance parts that have had multiple skims, this practice is not recommended.

Stress Relieving

Some shops perform a post-EDM stress relief heat treatment cycle to improve fatigue life. It is possible that dimensions of large parts may change slightly due to either deep freezing or tempering.

Programming Errors

I once wire EDMed a punch and die set that made 2 million parts before the customer determined that a significant geometry feature was missing. In fact, when they went to add a pierced hole as a result of a product change, the part did not exist in the location specified for the hole. While most programming errors are not as dramatic, merely choosing a programmed dimension from a nominal print dimension with a unilateral tolerance band can cause a part to fail inspection when everything else was done right. A feature that had a +.001/-0 tolerance that was programmed to nominal and is now .0002" undersize, is still a reject even though it was within a "tenth" on a side of the wire programmed path!

Despite this daunting list of potential sources of variability in the Wire EDM process, very accurate work is being performed by many shops on a daily basis. The purpose of this discussion is to raise the awareness of Wire EDM users that just because a machine has a ten millionths resolution control, producing parts to within a "tenth" is not a foregone conclusion. Producing very accurate Wire EDM work is difficult business. However, carefully attending to the controllable causes of variance within the Wire EDM process, healthy respect for the process's limitations, and just a little good luck can produce amazingly good results.

Next issue: **Sinker EDM variablilty.**

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