TechTips

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

Quality & EDM part 2

Last month we explored the potential sources of variability in the Wire EDM manufacturing process. This month we will explore the potential sources of variability in the Sinker EDM manufacturing process.

This list of contributing factors for variability in Sinker EDM work is even more daunting than for Wire EDM, because Sinker variability is a combination of the variability of the Sinker process plus the variability of the electrode manufacturing process. In addition, because Sinker EDM is a three-dimensional process, the extra variability associated with the Z axis compounds the possibility of error.

First we will examine the Sinker EDM process variability.

Components of Variability in the Sinker EDM Process:

Machine Movements:

Dielectric Bath: The weight of the dielectric oil in the work zone can be considerable. It is possible that a small amount of deflection of the machine structure will occur when the work tank is filled. This can cause position errors if the part was picked up with the work tank empty.

Roll, pitch, yaw: The way system of any machine (this applies to X, Y, 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 axes are exactly 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 exactly perpendicular to the plane of the X & Y axes. Deviations here can affect the position of cavities that are burned at different levels.

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 X,Y, and Z, the resulting error is .00017" in three-dimensional space.

Dynamic positioning: When the machine is in motion, 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. Dynamic positioning accuracy comes into play during orbiting.

C-Axis: The roundness of the C-Axis rotation, as well as its angular positioning accuracy (in arc seconds) can have a significant effect on overall Sinker EDM accuracy, especially when the C-Axis is used to index an electrode mounted a considerable distance from the center of rotation. Another critical consideration is the concentricity of the centerline of the tooling system attached to the C-Axis, as compared to the center of rotation of the C-Axis.

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 Sinker 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 measurements], 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 addition to the discharge energy, flushing pumps add significant amounts of heat energy via the pumping process.

Tooling System Repeatability:

As electrodes are exchanged during the course of a burn (either by hand, by tool changer, or by robot), it is critical that the tooling system datum relationship to the machine datum remains constant. Most popular tooling systems repeat to within .0001. Not only are X,Y, & Z repeatability important, but angular repeatability is critical also, especially for electrodes mounted a considerable distance from the tooling centerline. Lack of angular repeatability is one of the disadvantages of the 20mm shank type tooling.

Spark Gap Variability:

The spark gap can vary significantly, due to lack of dielectric cleanliness, especially in poor flushing conditions. This variability decreases with reduced power settings normally used in the final orbit sequence.

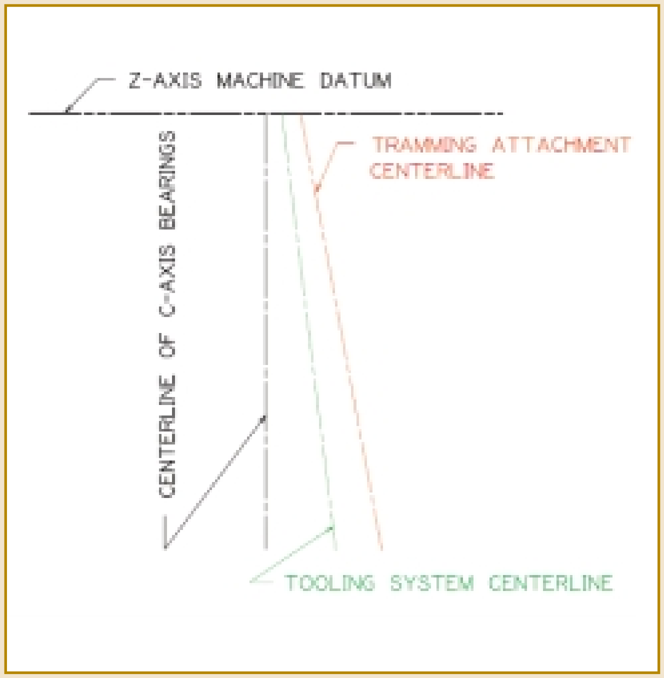

Figure 1

Setup Variability:

Blank Preparation: If you are going to work to a "tenth" the 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.

Electrode Mounting: For those electrodes that are not machined directly on the tooling, such as small blades or rods, the same care must be taken in electrode mounting as in workpiece mounting. Again, every "tenth" given up here is predictably added to the many variability factors we can't control.

Workpiece and Electrode Pick-up:

Picking up with an indicator: Some shops still position the machine reference relative to the workpiece reference using a "Tramming Attachment" that mounts in the tooling system reference and contains its own spindle bearings, allowing the workpiece to be picked up like in a Jig Bore. The downfall of this method is that often the "Tramming Attachment" spindle bearings are not very good, the axis of the spindle bearings is not concentric with the tooling system reference, and the axis of the spindle bearings is not perfectly parallel to the Z-axis of the machine. Often, this combination of potential errors means that even though the pick-up was perfect, the cavity is burned out-of-location. An extreme situation is shown in ***Fig# 1,*** which depicts the compounding effects of the tooling system and "Tramming Attachment" each being out of positional and angular alignment with the machine C-Axis. This situation can be vastly improved if an indicator is mounted rigidly to the tooling system, and rotation is effected via the C-axis itself.

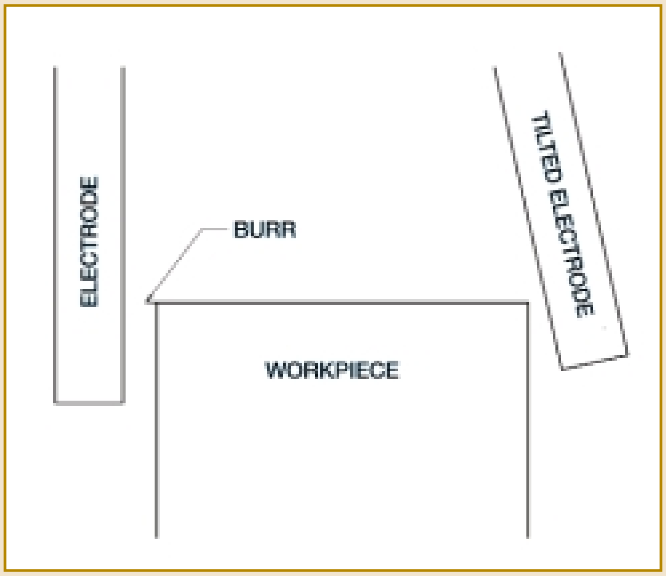

Figure 2

Picking up with the electrode: Some shops pick up the workpiece with the electrode itself. While this method eliminates all the possible variability of the indicator method, it adds a legion of variability's all its own. Any squareness, parallelism, or perpendicularity issues with either the electrode or the workpiece can adversely affect the final results. Also, the cleanliness of the pickup surfaces as well as any burrs can cause unexplained deviations. Both of these conditions are illustrated in ***Fig# 2***. Important note: It is always preferable to tram a block or an opening as opposed to doing a single edge pickup, since with tramming the operator gets the opportunity to compare the difference in the machine readings with the sum or difference of the electrode/workpiece dimensions as a double-check.

Picking up with a probe: Most knowledgeable CNC Sinker EDM users use a spherical probe to pick up both electrodes (if they weren't manufactured on the tooling) and workpieces. The spherical surface of the probe provides a constant condition for the machine's electrical sensing systems for best results. The two sources of variability in probing are the sphericity of the probe tip, the repeatability of the probe in returning to center if deflected by probing overshoot, and the relationship between the probe center and the tooling system center.

Electrode Wear:

No matter how accurately an electrode is manufactured, its surface will be degraded by electrode wear. Be it corner wear or volumetric wear, the cavity accuracy will be adversely affected. Despite the financial incentive to rough and finish with the same electrode, proper process planning to determine the correct number of electrodes and when to change them in the orbit sequence is essential to minimize this source of variability.

Unintended Orbit Effects:

As covered in detail in a previous article, the type and application of orbiting techniques can result in unintended cavity geometry degradation.

- Sharp corners become radii.
- Sharp corner dimensions, especially for small included angles, can change by a significantly larger amount than the orbit allowance.
- Three-dimensional distortion can be introduced.

Post-EDM processes:

Bead Blasting: Some shops bead blast parts after 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 fine finish final orbit burns, 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.

Components of Variability in the Electrode Manufacturing Process:

Now we will examine electrode variability, especially as it applies to 3-D geometry machined onto electrodes mounted on standard tooling in a machining center. We will begin by examining the additional variability encountered in a typical machining center used to fabricate 3-D electrodes.

Machine movements ***(Additional factors to those already listed earlier for sinker EDM):***

Dynamic positioning: When the machine is in motion, 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. Dynamic positioning accuracy particularly comes into play due to the high feed rates encountered during high speed machining of graphite electrodes.

B-Axis: The roundness of the B-Axis rotation, as well as the angular positioning accuracy (in arc seconds), can have a significant effect on overall electrode accuracy.

Spindle Temperature & Stability:

The stability of the spindle in the X,Y & Z-Axis directions is directly related to the temperature control and compensation algorithms applied to the spindle. The actual position of the spindle in Z can be quite different after hours at 15,000 rpm, as opposed to when it was cold during the picking up of the part and setting all the tool length compensations.

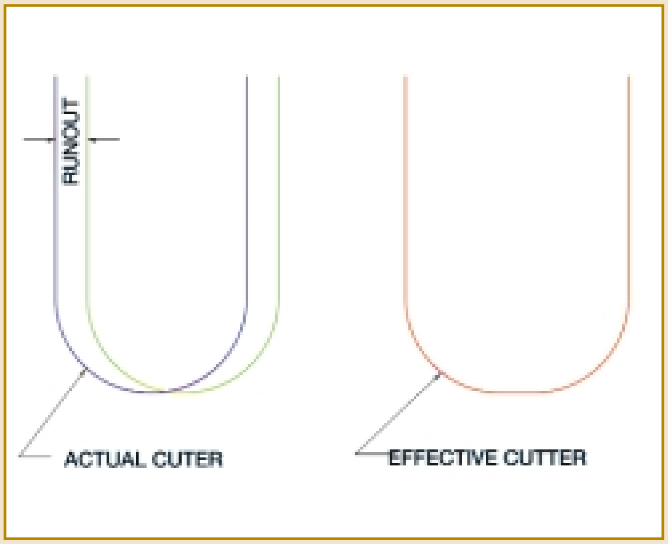

Figure 3

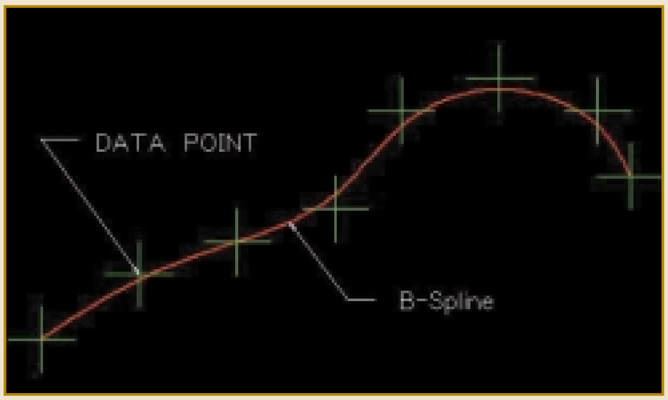

Figure 4

The spindle coolant media temperature should also be maintained within 2 degrees of the machine tool manufacturer's recommended temperature.

Toolchange Repeatability:

How well the tool holders repeat in the spindle with respect to run-out and Z-Axis repeatability will have a direct effect upon the quality of the electrode, as this factor alters the respective size and position of the cutter.

Tool Runout:

Tool runout is a critical factor in close tolerance 3-D machining, as a perfect ball end mill which is running out .001 will produce significant 3-D geometry errors. Most high performance electrode machining centers utilize either hydraulic or shrink fit tool holders that can hold cutter runout to a tenth or two. This effect is illustrated in ***Fig# 3***.

Tool Deflection:

Many people are surprised by the forces that can be generated when machining high density sub-micron graphite. These forces can translate into cutting tool deflection, resulting in 3-D form errors on small diameter cutters or those with large extensions.

Cutting Tool Form Errors:

The software generating the tool paths for 3-D machining assumes a perfectly spherical ball end mill of the correct spherical radius. It is extremely difficult to produce a properly relieved ball end mill to a .0002" radius tolerance. Deviations in cutter geometry translate directly in electrode geometry errors.

Cutting Tool Wear:

Even TIN coated or even Diamond coated carbide tools will exhibit some wear when cutting graphite. This wear will result in geometry form errors on the cutter, which will add variability to the generated electrode geometry if left uncorrected in the final cutting pass.

Tooling System Repeatability:

As electrodes are exchanged on the machine during the course of the machining process, it is critical that the tooling system datum relationship to the machine datum remains constant. Most popular tooling systems repeat to within .0001. Not only are X,Y, & Z repeatability important, but angular repeatability is critical also, especially for large electrodes with features that are a considerable distance from the tooling centerline. Lack of angular repeatability is one of the disadvantages of the 20mm shank type tooling. Any variability here adds to the variability that results when the electrodes are exchanged on the EDM.

Variability due to Programming Considerations:

Software geometry approximation: Most all 3-D CAD-CAM software applications translate the input 3-D geometry (3-D solids, cross-sections, point clouds, etc) into an internal mathematical database (wire frames, splines, nurbs, etc) for ease of mathematical manipulation. That conversion is necessarily done with some amount of allowed form deviation from the original data. This situation is illustrated in exaggerated form in ***Fig# 4,*** which depicts a B-Spline that is based upon a series of data points. That conversion tolerance necessarily adds to the uncertainty of the final electrode geometry. In fact, ISO and many military certifications require that CAD/CAM software be tested to verify its ability to accurately produce geometry. (Just because it came from a computer, doesn't mean that it's automatically correct.)

Post Processor geometry approximation: Most machining centers still execute 3-D geometry as a series of small straight line movements. The CAD/CAM software must convert its geometry model data into these small G01 movements. There is a tolerance associated with that conversion, since curved surfaces are being created by straight line

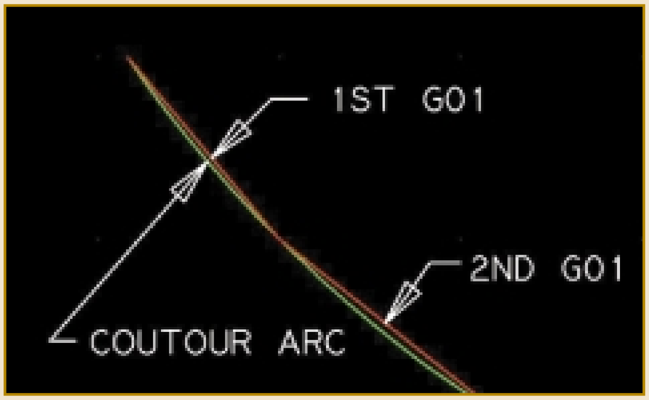

Figure 5

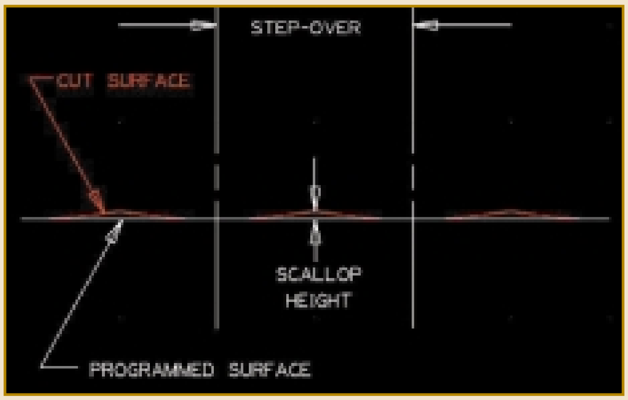

Figure 6

segments as shown in **Fig# 5**. This tolerance is often specified by the programmer. This conversion tolerance may add to the uncertainty created by the software geometry approximation.

Step-over scallop error: Often, the programmer is allowed to choose the "step-over" distance in a 3-D program. Small step-over (which can result in huge programs) result in smaller scallop heights. Scallops are a deviation from the true programmed path as shown in ***Fig# 6***.

Setup Variability:

Setup: The electrode tooling system master block 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.

Tooling System Master Block Pick-up: The tooling system master block must be picked up with the greatest of care, so that its datum is in exact relationship with the machine and programmed datums. In addition to X&Y, it is crucial that Z position be accurately registered. Again, every "tenth" given up here is predictably added to the many variability factors we can't control.

Cutting Tool Length Pick-up or Pre-setting: The length of each cutting tool must be measured and entered into the machine control's length compensation registers. Any inaccuracy of that measurement, either on the machine or with a pre-setter, will directly translate into electrode geometry variability.

Conclusion:

This daunting list of potential sources of variability in the electrode fabrication and Sinker EDM makes the Wire EDM variability we studied in part one of this series look like a walk in the park. The purpose of this discussion is to raise the awareness of Sinker EDM users that, just because the EDM and the machining center have ten millionths resolution controls, producing 3-D geometry within even a couple of "tenths" is rarely possible, let alone a foregone conclusion. Producing very accurate Sinker EDM work is extremely difficult business. However, meticulously attending to the controllable causes of variance within the Sinker EDM process and associated electrode fabrication, healthy respect for the process's limitations, and just a little good luck can produce amazingly good results.

Next issue: Measurement variability.

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