by Roger Kern

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

Improving Wire EDM PRODUCTIVITY

This issue, we will begin to explore the topic of Wire EDM Productivity improvement. First, we need to define Wire EDM productivity. Let me suggest that Wire EDM productivity is the over-all efficiency in processing jobs through the Wire EDM department in the shop. **The "inconvenient truth" concerning Wire EDM productivity is that for most shops, the largest potential for improvements will not come from increased cutting speeds.** However, since most users are focused on increasing cutting speeds, we will concentrate on this topic in this installment. We'll deal with other more significant potential productivity improvements in a subsequent article.

First, we'll examine some common myths concerning cutting speed. Then we'll explore the methods for optimizing Wire EDM cutting speed in detail.

Myth Busting

Myth #1: A larger wire always gives more economical performance

Many users today are running .012" wire in their machines to increase cutting speed. Some machines even utilize .013", .014", and even .015" wires to obtain record breaking performance. However, it has been my experience that in many cases, .012" wire is not necessarily the best choice.
Here's why:

- Wire usage and associated costs increase dramatically compared to .010" diameter wire. For a given spool weight, the length of wire (and therefore running time) is reduced by a whopping 40%.
- A lot of the extra power that a .012" wire can carry without breaking is consumed in producing a wider slot. A .012" diameter wire must remove approximately 15% more metal than a .010" wire.
- A larger diameter wire, along with its associated higher current levels, will typically leave more corner error than a smaller diameter wire. This may often result in either slower or more numerous skim passes.
- A larger diameter wire results in more cutting debris, a combination of workpiece and wire material. This means that filter and resin life will be reduced.
- The higher current levels normally associated with larger diameter wires will also result in reduced power feed contact life.

Thus, remembering that total performance is more than just raw cutting speed, it might be wiser to invest in a .010" diameter high performance wire than blindly reaching for that spool of .012" brass. (Please note that in tall workpieces or poor flushing conditions where wire breakage is an issue, a larger diameter may well be the best option.)

Myth #2: Always run the maximum wire tension

High wire tension is necessary to maximize accuracy. In single pass cuts, high wire tension will reduce corner error, belly, vibrations and deflections of the wire induced by flushing forces, especially in tall workpieces. In skim cuts, high wire tension assures maximum precision. However, not all jobs are +/- .0002" tolerance. For the numerous jobs with more relaxed tolerances, such as +/- .001" or larger, a lower level of wire tension will allow the machine to cut faster. Wire tension, combined with heat and the attacks of the spark upon the wire cross-sectional area, is what ultimately will break the wire. If we lower the wire tension significantly for thinner, less accurate jobs, we can apply more power to the wire without breaking it. For example, I often run only 600 grams of wire tension with .010" wire on relatively thin stacks of production parts.

Myth #3: High tensile wires are required for fast cutting

Many folks think that a higher tensile wire will better resist breaking in high performance cutting than a "softer wire". In many instances, this is simply not true, and in fact, quite the opposite is true.

How much tensile strength do we really need? A .010" wire with a tensile strength of 900N/mm^2 will support a static tensile load of 4,500 grams!

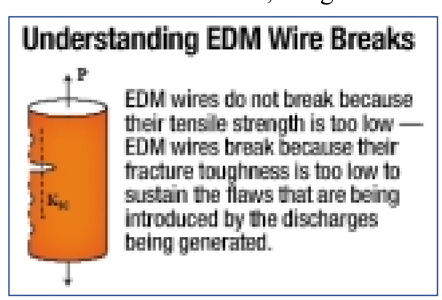

Figure 1

The most significant factor in wire breakage is not the tensile load on the wire, but the flaws created by the sparks which attack the wire's cross-section. ***(See Figure #1)*** It is common practice in tool design to avoid sharp corners, since a crack will often radiate from a sharp corner leading to the failure of the tool. Well, a pit mark from an EDM spark is just such a sharp

corner that can lead to a wire break. The property of a material to resist failures caused by cracks is often called fracture toughness.
(See Figure #2)

Figure 2

A softer wire will "give" slightly and absorb an overload rather than snapping.

Unfortunately, fracture toughness often decreases as the tensile strength of a given material increases. Softer (lower tensile strength) wires usually have higher fracture toughness than high tensile wires!

For example, two well known high performance wires from have tensile strengths of "only" 800 N/mm^2 yet both wires are successfully employed for both roughing and skimming to very high tolerances. Also, another well-known brand is only 490 N/mm^2, yet it too successfully cuts thick workpieces to high tolerances with significant tensile loads.

So, why do wire manufacturers produce high tensile wires? Because many customers, acting on the "more is better" principle, ask for them! Wire manufacturers are happy to comply, since it is less difficult to produce a wire with good straightness properties if the tensile strength is kept high.

Extensive wire testing has demonstrated that half hard wires will cut significantly faster than full hard wires of the same type.

Another factor in the improved performance of softer wires, is that they have better electrical conductivity than harder wires. During the drawing process, the hardness of the wire is increased by mechanical deformation of the wire. The electrical resistance of a wire is increased the more it is cold worked. Wires with lower electrical resistance will cut faster than like wires with higher electrical resistance.

It is important to note that wires with tensile strength lower than 800 N/mm^2 may not reliably auto-thread in a number of machines, since no matter how straight the softer wire is when it comes off the spool, it will acquire the curvature of the machine rollers in the wire path between the supply spool and the guides.

It is also important to note that smaller diameter wires, .006" and below, often do require higher tensile strength to withstand operating loads, since their cross section area is considerably reduced when compared to wires .008" and larger. Small diameter wires with half hard temper are not used.

Myth #4: The fastest cutting rate means the shortest cutting time

It is common to see a Wire EDM operator "fiddling" with the cutting parameters to get the last bit of speed out of the process, only to have the wire break ten minutes after he leaves for the night, thereby losing a whole night's burn. Or, how many times have you seen (or been) a Wire EDM operator "fiddling" with the cutting parameters to get the last bit of speed out of the process instead of setting up the next machine? Or, how many times has an operator abandoned the setup of an adjacent machine because he's constantly attending to wire breaks caused by a process running on the ragged edge?

Most night burns don't burn all night, so what difference does it make whether the cut finishes at 2:00 AM or 6:00 AM, as long as it's done when the 1st shift arrives. However, if the wire breaks and the job doesn't finish, not only are the nighttime hours wasted but the subsequent daytime schedule is blown also.

Reliable unattended burning is always more productive than unreliable attended fast burning!

Myth #5: If the wire costs 50% more it should cut 50% faster

There's an old saying that "Figures don't lie but liars figure." This myth nicely fits that description. The key fact that many people ignore is that the cost of the wire is a relatively minor portion of the total cost per hour of operating a wire machine.

Let's examine this situation in more detail:

First let's calculate the wire cost per hour assuming .010" premium hard brass running at 135mm/sec:

- 135mm/sec X 3,600sec=486m consumed
- P-5 5kg spool of .010" wire containing 11,700m costing $55.00
- $55/11,700m=$.0047 per meter
- 486m/hr X $.0047/m= $2.28/hr wire cost

Let's further assume that the total machine cost is $50.00 per hour, which includes wire, electricity, filters, wear parts, maintenance, labor, overhead, and financing.

Using these figures, the wire cost is less than 5% of the total machine hourly cost! Increasing our wire cost by 50% will increase our total machine cost by less than 2.5%. Therefore, any performance gain greater than 2.5% is pure profit.

In fact, based on the above analysis, one could conclude that, in many circumstances, *an "expensive" high performance wire will generate improved profitability even if you got your low performance wire for free!*

Often, the savings go far beyond hourly costs. I know of one Wire EDM facility that refused to consider switching to high performance wires "due to the cost". They then purchased sixteen additional wire machines to increase their capacity. Had they switched to high performance coated wire, they could have reached the same capacity with their existing machines!

Setting Optimization Techniques

Myth Busting aside, there is still often a valid requirement to increase the cutting speed for a given wire/workpiece combination.

At the conclusion of my last article, I stated that "those who plan to merely substitute these (coated) wires for Brass and just sit back and see big performance numbers may be sorely dis-

TEST BLOCK LAYOUT

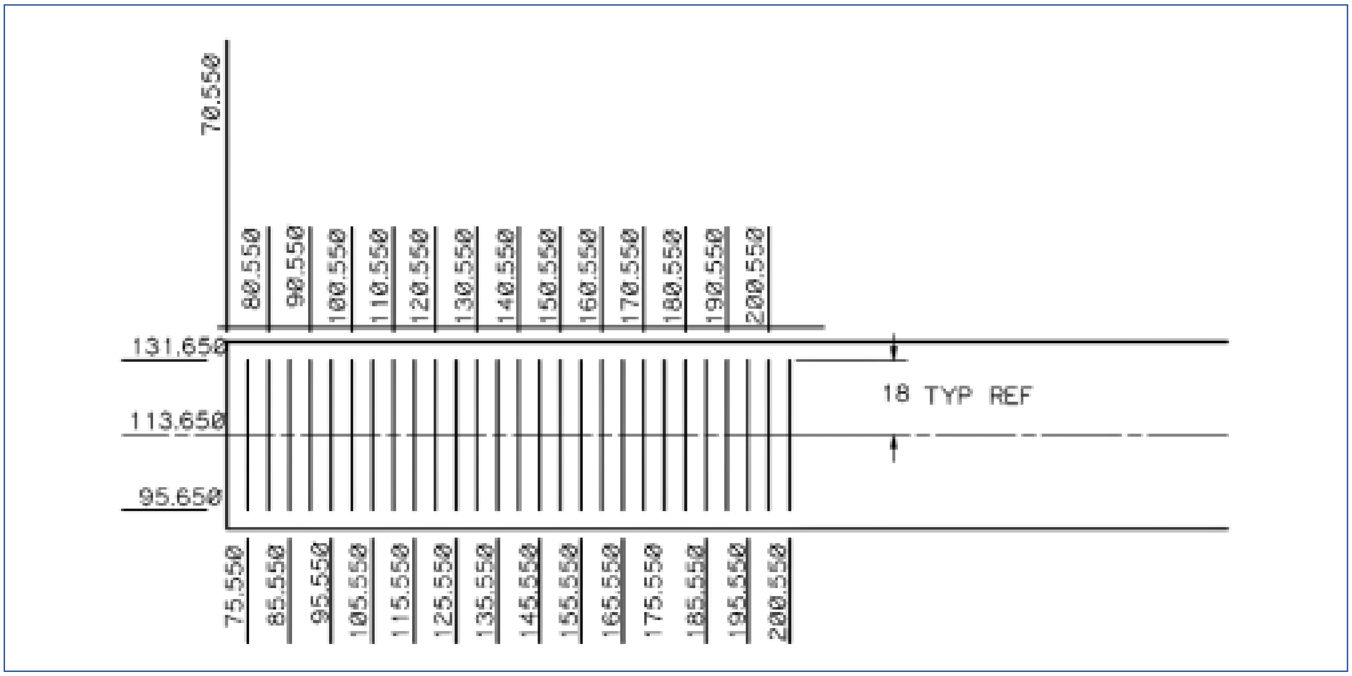

Figure 3

appointed." Let's take a look at a systematic approach to developing settings to optimize performance by improving existing technology for a new wire or application.

First, it is important to acknowledge that developing wire technology is not for the feint hearted. OEMs spend enormous amounts of money developing technology for their machines. It can easily take thousands of testing hours to develop complete technology for a new type of wire for just one machine! It would be foolhardy to imagine that we are clever enough to duplicate the results of that enormous effort in just a few hours of "fiddling" with the machine.

However, remember that OEM technology is inherently conservative because the OEM has to guarantee machine performance and cutting reliability over a wide range of cutting conditions, largely beyond their control. Using existing technology as a baseline, we can alter certain parameters to, in some cases, achieve significant performance gains.

A crucial prerequisite for performing machine settings optimization is to be certain that the machine is in A-1 condition. That is, the machine is currently performing to manufacturer's specifications, confirmed by replicating the factory test cut. Hours spent optimizing a defective machine will be totally wasted, since test results will only apply to the machine in its current unsatisfactory condition. In many such cases, test results may be totally misleading. I recently participated in an unproductive optimization session at a facility whose allegedly A-1 condition machine was subsequently determined to have totally worn out lower power feed contacts!

Please note that the following procedure is aimed only at optimizing the Rough Cut Technology, since this is often where the majority of performance gains can be found with the least risk. Optimization of Skim Cut settings is beyond the scope of this discussion.

Since my recommended approach is to build upon the OEM settings and not "re-invent the wheel", the first step is to choose OEM technology that comes the closest to matching our application, and using those settings as a baseline.

For the initial trials, I suggest straight line cuts originating some distance from either the edge of the block or starting hole. ***(See Fig. #3)*** for a drawing of the standard test block that I use for performance testing.

The first step in optimization is to make a cut at the base line settings.

My Golden Rule in this type of testing is to only alter parameters that do not increase the slot width or degrade the surface finish. This means, that in most cases, I avoid

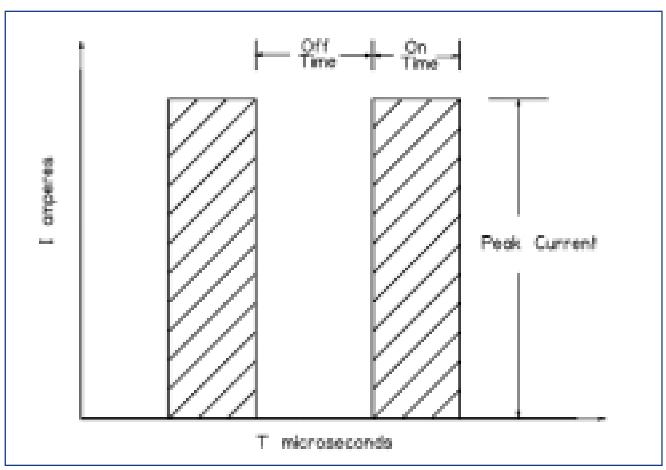

Figure 4

changing the open gap voltage, peak current or On-Time (note that in some instances I lower the On Time to improve the performance of certain Gamma wires). ***(See Fig. #4)***. This simplified graph plots a typical cutting pulse stream. Please note that the area defined by the On Time and the peak current is directly related to the spark energy. It is the spark energy that controls the depth of the discharge pits, which directly relates to the surface finish and slot width.

The remaining parameters subject to optimization are:
Off Time: This is the time between discharges. Off Time has no effect on discharge energy. Off Time is the pause between discharges that allows the debris to solidify and be flushed away by the dielectric prior to the next discharge. Reducing Off Time can dramatically increase cutting speed, by allowing more productive discharges per unit of time. However, reducing Off Time, can overload the wire, causing wire breaks and instability of the cut by not allowing enough time to evacuate the debris before the next discharge.

Servo Voltage *(Not Gap Voltage or Cutting Voltage):* Generally, this parameter determines how aggressively the forward feed responds to changing cutting conditions. ***(See Figure #5)*** The harder we "push" the servo, oftentimes the faster the machine will cut. If we push too hard, the gap will short out and cause instability and wire breaks.

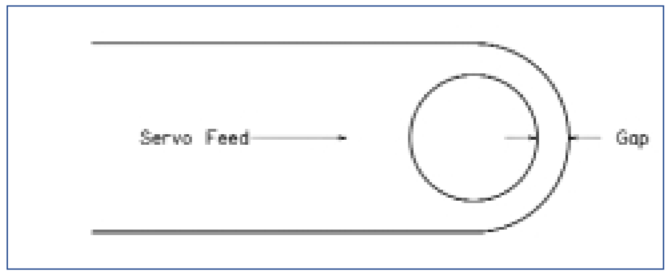

Figure 5

Safety factor: Most all machines have an "adaptive control" or "fuzzy logic" parameter (or parameters) which makes the machine either more or less aggressive. The job of this safety factor is to protect against wire breaks, but in many machines conservative settings can be altered to achieve significant performance increases.

A careful review of most machine manuals will yield the parameter names and range of possible values.

The key to successful performance optimization is methodical and small adjustments of individual parameters. It is also important to allow the machine to stabilize after each change is made and monitor the cutting rate and stability during a straight line cut.

I personally start with Off Time, proceed to Safety, and finally adjust Servo.

Once an optimal setting is determined, then the machine should be allowed to cut a significant distance at that setting to see if it is sustainable.

Finally, the setting should be tested on a square or contour with corner radii that are similar to your typical application. Often, the settings will have to be backed off to accommodate contour cutting.

Using this method, significant performance gains can often be achieved, especially for high performance wires. However, always keep in mind that, to some extent, you may be compromising reliability for speed.

This type of parameter modification is not for the casual, impatient, or novice, but the intelligent application of these principles will yield substantial dividends for those EDMers that are willing to push the envelope.

Any suggestions for future topics are welcome.
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