High Speed Milling Fundamentals

There once was a time when pundits predicted that High Speed Milling would replace Sinker EDM. As with many bold predictions, this one missed the mark. In fact, many shops have found that High Speed Milling (HSM) and EDM are complimentary processes, and that by adding HSM capabilities, these shops have opened a whole new world of opportunities to better serve their customers.

First, let’s look at what differentiates HSM from regular milling:

- Shallow cuts
- High spindle speed
- High feed rate

Sounds simple enough, but before you attempt HSM on your knee mill, you need to know that there’s a whole lot more to it than the three attributes mentioned above. More on these details later, but first let’s look at the reasons why more and more shops are adding this important capability.

HSM and EDM
Since this is an EDM publication, let’s first examine the EDM applications for the HSM process.

Electrode Making
HSM improves the electrode making process by a whole order of magnitude in three ways:

- Reducing electrode count: In the “good old days”, we often broke down complicated electrode geometry into a series of simple electrodes because, quite frankly, we didn’t have the capabilities to produce complex shapes. However, the penalties of multiple electrodes are longer fabrication and burn times combined with multiple possibilities of registration errors causing cavity mismatches. HSM and CAD/CAM changes all that. In many cases, we can now readily and efficiently machine complex shapes. (See Fig #1)

- Dramatically reducing electrode machining time: The combination of high spindle speed and high feed rates facilitates the very substantial reduction in the time it takes to machine electrodes.

Fig #1

- Producing electrodes previously considered “impossible”: HSM strategies now allow us to produce incredibly fragile electrodes with unheard of L/D ratios. (See Fig #2)

Fig #2

This extremely fragile electrode was machined in small steps from the top. At each step, the diameter at that step was finished before proceeding to the next step. Needless-to-say, only the top quality graphite must be utilized in this demanding application.
“OK,” skeptics may say, “but what about the graphite dust?” In years past, even though they were aware of the advantages of utilizing graphite electrode material, many shops stuck with copper to avoid the dust issue. “I don’t want my shop to look like a coal mine,” was the common refrain. And yes, machining graphite can be a messy business, even with dust control. The stuff gets everywhere including ways, CNC cabinets, and, of course, on people. Well, Chmer has changed all that with its unique Oil Shroud Technology. (See Fig #3)

The cutting process is encased in a shroud of dielectric oil which captures the dust and washes it away. The oil is then filtered by passing it through standard Sinker EDM dielectric filters. This process is so efficient that there will be no trace of graphite dust anywhere in your shop from HSM graphite machining operations, and because the Oil Shroud medium is EDM dielectric oil, there is no contamination of the graphite.

**HSM Combined with EDM**

There are numerous applications in which HSM will not be able to produce the final geometry, primarily due to internal sharp corner requirements. That being said, many shops have found that using HSM to finish some of the geometry and rough out the other geometry to near net shape allows them to concentrate their EDM resources only on the areas that truly need EDM, thereby reducing overall costs.

**HSM Replacing EDM?**

OK, let’s face it: There are a number of jobs that can be produced better and faster by HSM. Take for example, crankshaft and connecting rod forge dies (See Fig #4) which are now produced almost exclusively by HSM.

HSM has also replaced EDM in a surprising number of mold applications, producing cavities with fine finishes directly, eliminating electrode making altogether. HSM is now being utilized to machine steels as hard as Rc 62. (See Fig #5)

**Requirements for Effective HSM**

As mentioned earlier, effective HSM can only be achieved with the synergy of systems specifically designed for HSM.
**Machine Structure Rigidity and Stability**

HSM is not possible without a rigid machine structure. CHMER machines utilize a proven gantry design optimized by Finite Element Analysis. (See Fig#6)

Note that the machine table is totally supported throughout its travel. (See Fig #7) The machine structural elements are produced from Mehanite cast iron, known for its stability and vibration damping properties. The machine structure is monitored by temperature sensors that feed temperature information to the CNC which contains a thermal compensation map.

**Robust Spindle**

All Chmer HSM’s utilize HSK spindles, known for their robust construction and accuracy. All spindles are temperature controlled with a separate spindle coolant system.

**Motion Control**

High feed rates supported by effective motion control are a fundamental requirement of the HSM process. High feed rates, combined with small block moves, put incredible demands on the machine motion control system and the CNC. Chmer HSM’s are equipped with either oversize ball screws or optional linear motors and monitored by glass scales. The CNC must have lightning fast processing speed, multiple block look-ahead capability, and large memory capacity. An HSM program can easily contain 1,000,000 blocks. Chmer HSM CNC controls are purpose built for HSM with fast Intel processors and 2 GB flash memory.

**Safety**

At extremely high spindle speeds and traverse speeds, bad things can happen in a hurry with explosive forces released. Thus, HSM systems need to address these safety concerns. That’s why only carbide tooling should be used in the HSM process, since cutters will break rather than bend and whip out of control. Chmer HSM’s utilize bullet proof, reinforced glass for viewing windows, and all cabin doors are interlocked to prevent opening while the spindle is on.

**Tooling**

If the machine tool is the heart of the HSM process, the tooling is its soul. Tooling is not the place to even consider “going on the cheap.”

**Tool holders:** Tool holders should be of the highest quality and of the heat shrink or hydraulic type. EDM Network recommends Haimer and Schunk brands with the HSK “dual contact” interface.

**Cutting tools:** (See Fig #8 & Fig #9)

- **Graphite:** Diamond coated carbide tools are required to resist the surprising abrasiveness of graphite.

- **Steel:** Carbide with exotic coatings with as many as fifteen coating layers.

- **Geometry:** It is critical that the cutter geometry, particularly on ball end mills be closely controlled. The radius of the ball should be held within .0004”.

**Automatic tool measurement:**

- **Tool length compensation:** The CHMER HSM comes standard with automatic tool length measurement.

- **Tool diameter compensation:** CHMER offers an optional Blum automatic laser tool measurement system.

**Fig #8** This ball end mill has a ball diameter of .5mm (.0197”) and was used to rough cut the stamp shown in Fig #4. Most of the work was done with a .2mm (.0078”) ball end mill. Cutters are available down to .15mm (.0059”).

**Fig #9** This is an enlarged view of a miniature ball end mill. Note that the cutter shank is undercut below the ball diameter size.
Programming
A robust CAD/CAM system is essential to the successful application of HSM. You will likely be receiving solid models of the geometry that you will be required to machine, and manipulating, dissecting, and creating efficient tool paths from the model is essential.

Process Planning
It takes intelligent process planning to be successful in the field of HSM. Breaking down the geometry, choosing the cutting sequence, selecting the cutters, speeds, and feeds are all crucial to the success of HSM. Here is where the machine builder's application and training support becomes an essential component of the entire HSM package. Needless-to-say, an individual with substantial machining and programming skills will be a key part of your HSM capabilities. HSM is not for the faint of heart!

Inspection
So, you've machined this wonderfully complex electrode or mold. How do you know if it's any good? Complex geometries are beyond the realm of standard measuring tools and procedures. Thus, a CMM, along with inspection software capable of creating a measuring program from the original solid model, is the only way to effectively verify HSM workpiece quality.

Five Axis HSM (See Fig #10)
CHMER offers a full range of optional 5 Axis packages for both cantilever and trunion configurations.

HSM Application Tips
John Smith is the HSM Applications Engineer for EDM Network. John has eighteen years of HSM experience in the areas of Die/Mold, Aerospace, and Production, working with a wide variety of equipment including, OKK, Roeders, Makino, Heller, and Doosan. Here are a number of John's recommendations to help you achieve success in applying HSM.

Cutters
There are three different types of cutters to choose from: ball, flat, and bull nose. The best choice is a 2-fluted ball end mill. The ball end mill can handle the high cutting forces and allows you to get closer to the part's geometry. Use the ball end mill for all subroutines, roughing to finishing. For flat areas on floors and corners, use a bull nose to clean out the radius left from the ball. Then a Square mill can be used only if a sharp corner is needed.

Geometry
I like to use a cutter with a 15-20 degree positive rake angle and a relief angle of less than 10 degrees. On smaller tools, use a shank that is much bigger than the cutter diameter. This improves the rigidity of the cutter. The cutter then angles down from the shank. Example: I can use a 1mm cutter with a 6mm shank. Then, I only modify the draft angle unless I need to.

Coatings
There are 2 coatings commonly used: titanium carbonitride (TiCN) and titanium aluminum nitride (TiALN). TiCN coating is used for interrupted cutting because it can handle temperature changes well. The best choice is the TiALN. This coating can handle higher temperatures, (1,470) ° F vs (750)° F for TiCN, giving you higher rpm and higher feed rates. One newer coating is a titanium silicon nitrate, with the silicon acting as a shock absorber. Think of it as stepping in sand. The additional benefit of this coating, besides being stronger, is that it is more temperature tolerant. It is used mainly for workpieces harder than 52 Rc. This coating can also adhere to a sharper edge, and with a sharper edge comes a better finish. I sometimes use this on aluminum to obtain a chrome-like finish. Another benefit of this coating is that it also lasts longer.

Stepovers
It is important to have proper step-over to let the heat out. Roughing operations should be 23-40% of the tool diameter. When a step-over is too great, the tool cutting edge doesn’t have time to cool down. The heat then builds on the flute. The coating deteriorates causing the tool to burnout.
For finishing, use this formula: (See Fig #11)

Radial step over = $\sqrt{4 \times (\text{cusp Height} \times \text{Tool Dia}) - 4 \times (\text{cusp height}^2)}$

Cusp height = \frac{\text{Tool dia}^2 - \text{radial step over}^2}{4}$

Other Hints
- Use small cuts very fast. This decreases cutting forces, creates reduction of production time, and dissipation of heat through the chips.
- Ramp on and off (no plunge cutting). Use a helical ramp when starting part center.
- Strategies:
  - For roughing, use wide shallow cuts.
  - For finishing, use a cusp height of minimum .00005". (Yes, you read that right: 50 millionths!)
  - Keep a uniform stock allowance.
  - Keep constant step overs/avoid thickness changes. (It's like hitting a speed bump.)
  - Avoid programmed sharp corners. (See Fig #12)

- Add semi-finishing path or paths to better finish and accuracy.
- Segregate geometry separately. Obtain the best path for individual geometry. (See Figs #13-16)
- Use a subroutine that attacks the part at a 15-45 degree angle. Using a ball end mill, you can utilize the whole tool, thoughout the contour and the tool wear will be from tip to the ball.

Fig #12  Sharp corners in the path of an HSM program should be avoided like the plague. The upper path in this figure is the proper one.

Fig #13  This is the solid CAD model.

Fig #14  The part is rouged from the solid blank with a square end mill in steps.

Fig #15  The geometry is now semi-finished with a ball mill.

Fig #16  Selective areas (in this case the top) are then finished with the appropriate size ball end mill.
But What About the Cost?
No doubt you've heard the stories out there about HSM machining centers costing $400,000 or more. CHMER has broken the cost barrier to shops’ entrance into the HSM world by introducing a rigid, high quality, highly accurate, dependable line of HSM's that can be tailored to your needs at a fraction of the cost of other brands.

About CHMER
CHMER (pronounced “shimmer”) has a long, proud history in the EDM industry. Founded in 1972 as a Taiwanese repair shop for Japax EDM’s, CHMER started producing its own Sinker EDM in 1975. CHMER manufactured their first CNC Sinker (a first for Taiwan) in 1985 and their first Wire EDM in 1987.

For a period of approximately 15 years, CHMER also built Wire and Sinker EDM’s under private label for a number of well-known brands.

CHMER currently produces 110 machine tools per month consisting of CNC Sinker EDMs, Wire EDMs, Small Hole EDMs, and CNC Machining Centers.

CHMER has recently celebrated their 40th anniversary of production, and in early 2010 moved into their new 250,000 square foot manufacturing facility. This state-of-the-art manufacturing facility has the capacity to produce in excess of 200 machines per month.

About EDM Network
EDM Network, headquartered in the Chicago suburb of Sugar Grove, has been the exclusive importer and service provider for CHMER since 2000. Over the last 15 years, they have installed over 600 CHMER machines in the U.S. in addition to taking over the service of more than 400 CHMER machines sold previously. The U.S. installed customer base includes many Fortune 500 companies. For the last ten years, EDM Network has been CHMER’s “Top Export Dealer” in the world! EDM Network has been selling and supporting EDMs since November 1992, however its founder, Ron Vogel's EDM roots go back even further to the early development of America’s first Wire EDM at the Andrew Engineering Company in 1972. In addition to the new CHMER EDMs and machining centers, EDM Network offers fully refurbished EDM’s, EDM consumables, tooling, parts, and service.

Contact:
EDM Network, Inc.
1974 Bucktail Lane
Sugar Grove, IL 60554
888-289-3367
www.edmnetwork.com