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▶ BY BILL KENNEDY, CONTRIBUTING EDITOR

Force Field

Getting a grip with electropermanent workholding.

About 250 B.C., Greek mathematician Archimedes said, “Give me a lever long enough and a place to stand, and I will move the earth.” In other words, force without foundation is futile.

It’s the same when metalcutting; you can have a high-horsepower machining center and a rugged milling cutter, but if your workpiece isn’t held securely, at best, you’ll get low-quality results. At worst, you’ll be ducking flying parts.

Obviously, the clamping pressure of a workholder must exceed the machining forces, but applying the correct pressure is not as simple as lining up some clamps and tightening them down. Careful application of clamps or vises is required. Plus, long setup times can also result, boosting per-part costs. In addition, if you need to machine the entire periphery of a part, you may have to stop in midcut and move the clamps. Uneven clamping forces can cause parts to vibrate or can produce distortion.

One possible solution is magnetic workholding. It can reduce setup times, enable uninterrupted access to five sides of a workpiece and provide a strong and uniform holding force.

Electropermanent Attraction

Both permanent magnets and electromagnets find use in workholding.

In permanent magnetic chucks, the magnets are mechanically moved to clamp or release the work. These chucks are reliable and simple to operate and are convenient options for light levels of machining. But as they grow big enough to handle large workpieces and heavy cutting forces, the mechanical force needed to make them work becomes excessive.

Electromagnets can be simply switched on and off but are dependent on a steady flow of current. The possibility of a power failure during machining raises safety concerns, and the need for connecting cables can limit their applicability.

In electropermanent magnets, a short burst of electrical power switches the magnetism on or off. Thus, continuous power is unnecessary, making these systems perhaps the most applicable magnetic workholders for metalcutting. An electropermanent magnetic chuck employs two sets of permanent magnets. One set is positioned within electric coils that enable the magnets’ polarity to be switched with a strong burst of electrical energy, typically 500v DC for about a half a second. A second set of magnets with equal power balances the switchable set.

When the chuck is off, the magnetism of the switchable set cancels that of the fixed set, and the magnetic energy, or flux, flows between the two sets of magnets within the chuck. When the chuck is switched on, reversing the polarity of the switchable set of magnets, the flux of both sets flows through the workpiece and creates grip.

Electropermanent chucks can be mounted on pallets or tombstones. After activating the chucks’ magnetic grip and clamping the workpiece(s), cables can be disconnected, freeing the mobile workholder for travel through the machining process. Electropermanent chucks typically are available in sizes up to about 24"×40"×3". For larger machine tables, multiple chucks can be ganged together.

Today’s chucks feature rare-earth neodymium magnets that can produce a grip of up to 11 tons per square foot.

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Jim Montoy, a machine operator at steel plate processor Olympic Steel, installs pole-extension blocks onto electropermanent magnetic chucks. Magnetic chucks allow Olympic to machine around the edges of and through workpieces. Montoy said the facility draws up charts for every part machined to keep track of where cutting must be done so the blocks are located accurately and are never in jeopardy of being accidentally cut.

Grasping Solutions

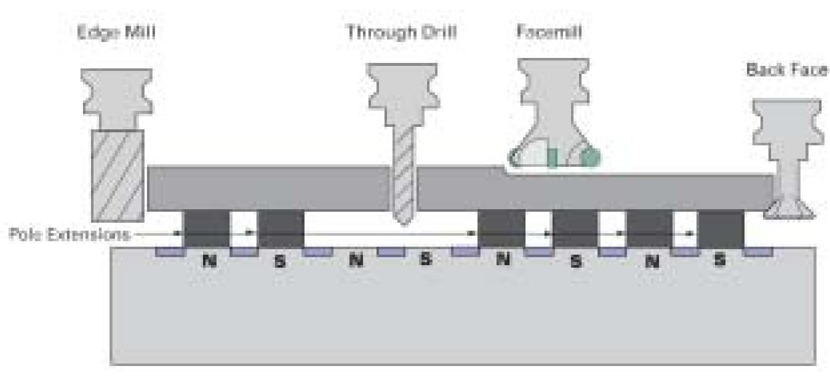
Tom Neil, operations manager at the Chambersburg, Pa., steel plate processing facility of Olympic Steel Inc., first looked at magnetic workholding when problems arose in the machining of flat steel end plates for asphalt rollers. The circular plates are 1.25" thick and 62" in diameter with a 24"-dia. hole in the center. Olympic mills and chamfers the circumference of the parts to prepare them for welding. The job is done on a custom-built, bridge-type machining center, which has 100"×200" travel and features a 25-hp head.

At first, Olympic employed a series of conventional bolt and rocker clamps around the periphery of the part, but that arrangement required repeatedly stopping the cut, climbing up on the machine and moving the clamps. "It took a lot of time and was tough on your back," said operator Jim Montoy.

To save time, Olympic made a bar clamp to grip the plate by its center hole. That eliminated in-process clamp changes, but another problem arose: vibration and tool chatter, especially with the 45° milling cutter used to create the chamfer.

After seeing magnetic workholding in use at a customer's shop, Neil installed six magnets from WEN Technology Inc., Raleigh, N.C., grouping them in three sets of two and positioning them in one quadrant of the machine table. Clamping the plate now involves simply placing it on the magnets with a forklift and pushing the button to activate the magnets.

"We easily cut our setup time in half," Neil said.



WEN Technology

Pole extensions lift a workpiece off a magnetic chuck to provide clearance for through-drilling, edge milling, facemilling and back machining.

In addition, the magnetic workholding provides grip sufficient to enable the facility to increase cutting speeds and feeds by 30 percent.

Olympic's flat-rolled products often require edge finishing, drilling and tapping. To gain access to the edge of the plates and permit through-drilling, the shop employs 2"-high steel blocks that act as extensions of the magnets' poles. The poles are topped with rails that are drilled with a series of holes. The blocks have pins that drop into the holes. When the magnets are turned on, the extensions are locked in place.

The blocks raise the plates and permit milling around their edges. Where through-drilling is required, blocks are removed to create clearance.

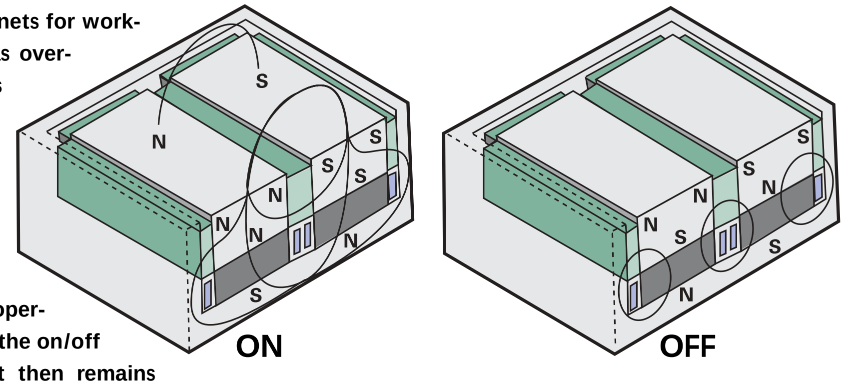
Where appropriate, Olympic also uses larger blocks at points around the plates' peripheries to locate them in the X and Y axes.

Flat-Out Grip

A magnetic chuck produces a broad and strong area of grip. If a workpiece is bowed to start and somewhat flexible, a magnetic chuck can pull it flat. For Olympic Steel's Neil, that's an advantage. "We've had instances where, for one reason or another, we've had slight bows in parts after they've gone through our burning operation. We put them on the magnet, and it sucks them down tight. It's powerful enough that it will pull the bow right out of the part. When we're finished machining, we let it go and the bow comes back. We then straighten the part out in a press. We gain because we're not machining it bowed."

However, not every part benefits from being pulled flat. Asymmetrical parts need asymmetrical support. The answer is adjustable, or self-shimming, pole extensions. These are basically solid extensions sliced in half at a 45° angle and held together with springs. After a workpiece is located on the chuck by three solid extensions, the self-shimming extensions can com-

One problem with the utilization of magnets for workholding in metalcutting applications was overcome when electropermanent magnets started to be used. Electromagnets, while strong enough for the tasks, must have a continuous flow of power to keep them magnetized. This means that if a power failure were to occur, the workpiece would be released. On the other hand, the circuit of the electropermanent magnet only uses power during the on/off switching process. The magnetic circuit then remains either on or off indefinitely until switched again, meaning no loss of magnetic grip if power were to be cut.



WEN Technology

press or be lifted (by the magnetic force) to maintain contact with uneven surfaces. When the magnetic chuck is switched on, the workpiece and extensions become a solid unit.

Thornton Industries Inc., Albion, Pa., machines multiton steel parts for the forge industry. The company employs magnetic workholding from Tecnomagnete Inc., Troy, Mich., to hold both new and rebuilt parts on horizontal boring mills.

President Matt Thornton said, “Sometimes we have parts that have been rebuilt and welded, and the plates have warped. The only way to hold them on a magnet is to have self-shimming pole extensions that compensate for the warpage and for the small amount of weld that’s above the surface.”

Self-shimming extensions permit multiple operations to be completed in one fixturing, which can help maintain consistent surface finishes.

Thornton Industries works at tolerances typically in the 0.002" to 0.005" range. “We worry about flatness and perpendicularity of bores,” Thornton said. “There, the magnets are definitely an advantage, because, depending on how much pressure you put on the part, if you have to rechuck it to skim another portion of the plate, it never winds up in the same spot. The part moves. You have a hard time matching surfaces.”

Limits to Its Grasp

Paul Van Every, regional sales manager for Tecnomagnete, readily admits a magnet has drawbacks. “There are times when it doesn’t work.”

Like on nonferrous parts. A magnetic chuck is worthless for directly holding a plastic or aluminum workpiece.

However, nonferrous workpieces can be clamped in vises or other fixtures that can in turn can be clamped to the machine bed with magnets, resulting in decreased setup times and enabling multiple parts to be machined at one chucking.

Meanwhile, different ferrous alloys exhibit different magnetic characteristics.

Because of their high iron content, “hot-rolled and cold-rolled steels are the best,” said John Knight, sales representative for O.S. Walker, Worcester, Mass. As alloying additions reduce the percentage of iron, “each material after that is going to have some reduction in holding power,” he added.

John Powell, president of WEN Technology, said there is a limit to every material’s susceptibility to magnetic attraction. Cast iron is less magnetic than steel, because there are flakes of carbon in it. It’s more like a sponge than it is like a block of steel, Powell said.

Stainless steel, with higher chromium content, is also less magnetic than plain steels.

Magnetic chuck providers recommend numerous ways to compensate for the lower holding forces for various alloys, such as the use of stops on the chuck face and utilizing higher machining speeds and lower chip loads.

Workpiece size has a large bearing on successful application of magnetic workholding. Basically, the bigger, smoother and thicker the workpiece, the better.

Van Every said, “The rule of thumb is, if the part fits in your pocket, buy a vise.” But he added that there are ways to magnetically hold even small parts, and the effort can be worthwhile, considering the potential for savings in setup time.

The following companies contributed to this article:

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A rolled-steel workpiece held by a magnetic chuck is machined at Olympic Steel.

Thornton concurred. He said one way to magnetically hold a smaller part is to surround it with a larger one that locks it in place. “Or, if it’s a repeat part, you can machine into solid pole extensions and create a ‘nest’ that you can drop the piece into,” he said. “When you turn the magnet on, the nest holds the part in place.”

The more part surface area there is to contact with the magnetic chuck, the stronger the grip will be. Thus, the large, flat steel plates Olympic machines are excellent candidates for magnetic workholding.

Thornton Industries must deal with more variances. “We have some parts where one side has a good area to cover the magnets, but when you flip them around, there’s a bunch of obstructions in the way,” Thornton said. “There is no way to really use a magnet to hold on to them properly. So we’ll get some clamps up there, too.”

“Remember, there is a limitation to magnetism’s affect on a material,” Powell said. “At some point, when the workpiece gets so thin that there’s no more room to hold all the magnetism, funny things start to happen. First, you will notice that the chips on the top of the workpiece will start to stick. Next, the holding power will go down. Holding force is a function of the flux density squared; halving the flux density cuts holding power 75 percent. So as soon as you start limiting the flow, your holding force goes to hell in a handbasket in a hurry."

On its Web site (www.wenmag.com) WEN Technology offers a calculation program that provides a basic look at the cumulative effects of different factors on magnetic workholding performance for milling. Data considered include magnetic chuck size and power (WEN products only), workpiece alloy and size, cutter size and machining parameters. Among the calculated results are cutting force, holding force and feed rate, along with a summary that recommends any changes that might be necessary for effective workholding.

Cost Per Part Produced

Magnetic chucks cost more than clamps, but Van Every said potential users should look at the big picture. "It's what the parts are worth and how much setup time is worth," that's critical to evaluate, he said. "Not what the clamps will cost you."

Neil added: "You can see there's a substantial savings from just being able to blow the part off with an air hose, turn the magnet off, pick up the part, put the next part on and turn the magnet back on. Plus, it's allowed us to use carbide drills and faster drilling operations than we had before." He said his prepurchase justification analysis determined that Olympic would get a return on its investment in 9 to 12 months.

Thornton pointed out that a setup for a big part with conventional clamping might take 4 to 5 hours. "But with the magnets," he said, "it takes 2 hours, if that."

There is a long checklist of workpiece material and size factors as well as operational considerations that determine whether magnetic workholding is the answer for a shop's workholding needs. But those who find the technology fits the bill might recall another exclamation by our mathematician Archimedes: "Eureka! I have found it!"