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▶ BY BILL KENNEDY, CONTRIBUTING EDITOR

Growing use of powder metals is creating new machining challenges.

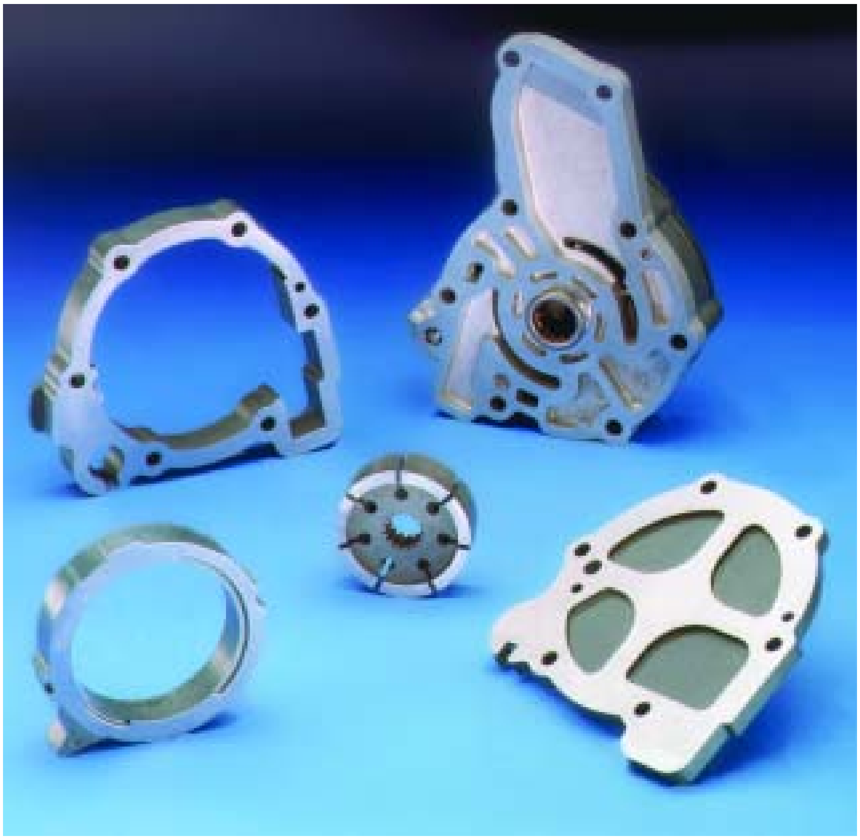
POWDER SURGE

The use of powder-metal parts in automobiles is rising. Industry sources say that between 1977 and 2003, the P/M-part content of a typical family vehicle produced in North America more than doubled, to over 40 lbs.

Typical P/M auto components include connecting rods, bearing caps, transmission carriers, valve seats and gears.

The use of P/M parts is rising in other industries, too, as more manufacturers discover their advantages. Among them is the ability to fine-tune the metal mix to enhance certain properties of the final product, such as its density, strength or wear resistance. And, because the part is pressed to shape,* minimal—or sometimes no—machining is necessary.

Kimberly Pontius, a 26-year veteran of the tool and die industry and executive director for corporate and continuing education services at Ivy Tech State College, Fort Wayne, Ind., called P/M parts the "wave of the future. They offer the same thing as rapid prototyping. Instead of starting with something and taking material away to make a product, you're starting with nothing and constructing the product you need. That dramatically reduces the waste stream, energy consumption and [related] environmental issues."


MPIF

The automobile industry is the biggest user of P/M parts, such as these components for a transmission oil pump.

Machining Considerations, Tips

A major advantage of using P/Ms is the ability to produce complex parts to near-net or final shape.

"The closer you can get to blueprint tolerance, the better off you're going to be," said Woody Haddix, president of the Lovejoy Sintered Technologies Division of Lovejoy Inc., Downers Grove, Ill. "It doesn't make sense to machine something when you can press it."

Many P/M parts, however, do require machining. The nature of the pressing process precludes formation of features such as back angles, undercuts and cross-holes, which must be machined after sintering. Moreover, because the tolerance on length that is possible with the P/M process generally is, at best, 0.003" to 0.005", addi-

**The powder is pressed to shape in a die, then sintered at temperatures around 2,000° F. The powder doesn't melt, but mechanical bonds formed during pressing are transformed into metallurgical bonds during the sintering process.—Ed.*

tional machining may be required to meet a customer's requirements.

James Dale, vice president for member and industry relations at the Metal Powder Industries Federation, Princeton, N.J., said, "A fair percentage of P/M parts don't get machined; it depends on the application. However, many P/M parts are being machined today because of the [tight] tolerances that are being requested."

Valenite developed this solid-carbide, 2-flute reamer to machine P/M valve seats. The tool features a PCBN blade.

When a material offers unique performance advantages, it usually provides unique machining challenges, too. Powder metals are no different.

Because the sintering process does not actually melt the powder, pores form between the grains. This porosity means that machining a P/M part involves interrupted cutting, at the microscopic level.

The vice president of product and business development at P/M parts manufacturer The Wakefield (Mass.) Corp., Lyle Williams, said, "It isn't like machining a solid; it's like machining gear teeth." The porosity also limits the amount of heat the workpiece can absorb. As a result, much of the heat enters the cutting tool.

"When you are cutting air, you're not effectively dissipating heat," said Steve Baker, director of engineering at Allied Sinterings Inc., Danbury, Conn. Adding to the problem of heat buildup is that many P/Ms do not generate chips, which remove heat from the cutting zone.

Williams said that cutting tools applied to P/M parts often suffer abrasion wear and chipping. He pointed out, however, that maintaining a sharp cutting edge and running at high cutting speeds will minimize these problems.

Concurring with that assessment is Kurt Ludeking, threading and grooving product manager at Valenite, Madison Heights, Mich. And, because of the abrasiveness of most P/Ms, he recommends that machinists start with their most wear-resistant carbide grade. Other effective tool materials for P/Ms are cermet and polycrystalline cubic boron nitride.

The director of special projects for Valenite's Modco custom tools division, Jim Robinson, said P/M valve seats used in autos contain large quantities of free carbide particles. They can wreak havoc on tool life, increase tool pressure and degrade part quality.

Because of the hard particles, machinists tend to run at very slow speeds and feeds, said Robinson. "That's probably making the condition worse—especially the slow feeds, [which can cause] a P/M part to act like a grinding wheel. I think folks are a little timid when they machine these parts."

He said spindle speeds typically are in the neighborhood of 300 sfm and feeds are 0.002 ipt to 0.0045 ipt. "We think that the correct speed is closer to 600 or 700 sfm," said Robinson, and "the feed should be somewhere between 0.0045 ipt and 0.006 ipt."

Robinson's group has developed special tooling to improve part quality and tool life when machining the seats. The tools incorporate blade-style cutting edges with PCBN along their entire length rather than just at their tips. The result is a narrow, rigid tool that can be ground more often and is easier to index. The free-cutting nature of the design makes it capable of maintaining a rounder, more accurate valve seat that fits within the confines of modern valve arrangements.

Improving Machinability

The ability to custom-blend powder metals has led to wide differences in their machinability, according to Robinson. "There are a lot of variations among P/Ms," he said. "When you say what the constituents are, you almost have to identify the manufacturer. There are differences in the way the concoction is 'baked,' if you will. It's sort of like an insert. We all use the same materials, but we mix them different ways and the end result, in some cases, is drastically different."

Greg West, vice president of operations for National Sintered Alloys Inc., Clinton, Conn., said the hardness of the individual powder particles is a key

MPIF publishes P/M machinability ratings

The "Standard 35" document, published by the Metal Powder Industries Federation, provides technical data about powder metals. The "Structural Parts" edition of the standard includes a machinability section.

Listings are based on data drawn from drilling tests performed on a wide variety of P/Ms. The testing involves drilling until a certain level of wear, or breakage, occurs. AISI 1045 steel serves as the baseline material, and the test results are normalized so that 1045 has a machinability rating of 100.

For example, a copper/steel P/M containing 2 percent copper and 0.8 percent carbon (designated FC-0208) has a machinability rating of 22. The same P/M with a 0.5 percent addition of manganese sulfide has a rating of 181; with resin impregnation, the rating is 286; and with both impregnation and the MnS, the rating is 305.

MPIF points out that the ratings do not take into account the effects of density, and the ratings may or may not be applicable to other machining operations.

MPIF Vice President James Dale said the rating system "gives you a relative idea of how you can expect a P/M material to machine." He added that consistent P/M manufacturing practices are essential to assuring the validity of the ratings.

—B. Kennedy

factor in a P/M's machinability. "In general, the more alloying elements you add, the harder the material is," he said.

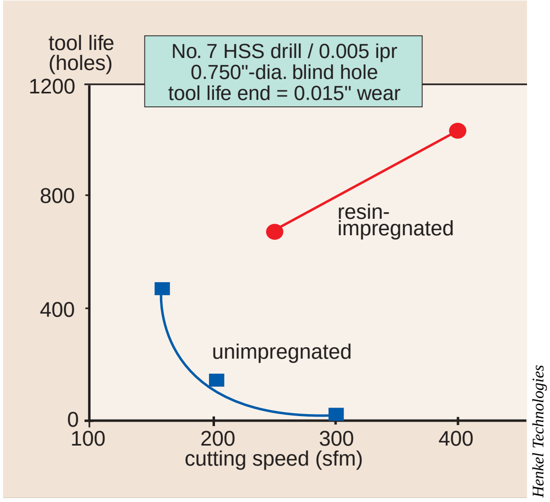
Allied Sintering's Baker added, "If you steer clear of the highly alloying elements—the ones that tend to create martensitic structures in the steel—then you're better off in terms of machinability."

P/M suppliers have developed methods for improving the machinability of their products. One is resin impregnation, in which an anaerobically cured, plastic resin is drawn into the part's pores via vacuum.

West said resin impregnation can provide a "huge improvement" in machinability. "It basically fills in the pores, reducing the interrupted cutting, and the plastic acts somewhat as a lubricant."

Bob Remler, senior impregnation specialist for Madison Heights, Mich.-based Henkel Technologies, supplier of Loctite porosity sealant, said resin impregnation helps reduce machining costs a number of ways. Among them are increased tool life, machinists can run tools at higher speeds and feeds, and finer surface finishes are obtainable.

To illustrate the effects of impregnation, Remler cited a turning operation in which a coated-carbide insert was applied to an unimpregnated P/M part at a 300-sfm cutting speed, 0.002-ipr feed and 0.049" DOC. The tool made 16 passes before it reached 0.015"of flank wear. On an impregnated part, an identical cutting tool run at the same parameters completed 825 passes before reaching the 0.015" level of wear.



In tests on an impregnated material, drill life increased as speed rose. The opposite was true for tests on an unimpregnated material.

Remler said the improvement can be so significant that shops should try to design machining processes around the benefits impregnation provides. He added that the higher the cutting speeds are, the more pronounced these benefits become.

"Machining costs can be reduced by 75 percent," he said. "Eight cents worth of impregnation per part can save in excess of $1 per part in machining costs, on certain applications."

Another way to fill the pores of a powder metal, and in many cases boost its machinability, is by copper infiltration. In this process, a copper slug is placed on an unsintered P/M part and, together, they are sintered at a temperature above the melting point of the copper. When the copper melts, it is absorbed uniformly into the material's pores.

"The main reason for infiltration is to increase the tensile strength and the transverse-rupture strength of the part," Wakefield's Williams explained. "But it often improves machinability, too, because you've gotten rid of the porosity. And copper, being softer, tends to act like a lubricant."

Copper infiltration isn't always cost-effective, though, as is the case with the microminiature P/M gears that Allied Sintering produces. One gear is ⅛" in diameter and has a diametral pitch of 78. Copper infiltration would be too labor- and time-intensive for such a small part, said Baker. "If you're going to do that part for a penny apiece, which is what we do it for, you can't afford to spend time copper-infiltrating it, because it then becomes a 5-cent part."

Additions to the powder mix itself also can improve machinability. Some P/M suppliers add manganese sulfide and other materials to improve machinability, augment lubricity and reduce friction.

A denser P/M part often machines more easily than one that is porous, because interrupted cutting is reduced. To increase density, some P/M parts are re-pressed, or "coined."

Analyze First

As with other manufacturing operations, the successful machining of P/M parts hinges on taking a systematic approach.

"You need to engineer not only your final product, you need to engineer your process," said Mike Finn, project manager for materials at TechSolve Inc., a Cincinnati consulting service specializing in manufacturing and technology issues. "You can't just throw the part up on the lathe and machine it to size, tolerance and finish. You have to consider all the interactions that come into play in the

The following organizations contributed to this report:

Allied Sinterings Inc.
(203) 743-7502
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Henkel Technologies
(248) 364-4700
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Ivy Tech State College
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Lovejoy Sintered Technologies
(630) 852-0500
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Metal Powder Industries Federation
(609) 452-7700
www.mpif.org

National Sintered Alloys Inc.
(860) 669-8653
www.pm-nsa.com

TechSolve Inc.
(513) 948-2000
www.techsolve.org

Valenite
(800) 544-3336
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The Wakefield Corp.
(800) 548-9253
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machining system."

As an example, he said that the density and hardness of a P/M determines the extent that resin impregnation would improve its machinability. Cutting speed would also have an effect. If the speed were too high, the pressure and temperature would be too great and the resin would simply vaporize.

As knowledge about machining P/Ms increases, the number of manufacturers producing parts from them undoubtedly will grow. Through 2020, according to MPIF, the powder-metal industry has a goal of increasing P/M usage 12 percent annually in the automotive market and 25 percent in non-automotive markets.

"I think you're going to see a lot more P/M research and development," said Ivy Tech's Pontius, adding that "you are going to see more and more parts that can benefit from the strength and wear characteristics of P/Ms."