Machining

A Cutting Tool Selection Guide: Ferrous vs. Nonferrous Metals

Kip Hanson | Nov 27, 2018

Does it matter if a metalworking material is ferrous or nonferrous? The most important factor is understanding how any material works with your cutting tools in your machines—and that does matter, find tooling makers with metallurgy knowledge. Find out what you need to know about the major differences in metal types for machining.

Ask any machinist to define the word "ferrous" and you'll likely hear the same answer: Ferrous metals are the ones that rust—carbon steel, cast iron, tool steel and so on. This statement, though true, is incomplete, as the metallurgical definition is both more specific and encompasses a much broader range of metals.

"Simply put, ferrous materials contain iron," says Aaron Schade, program manager for Kennametal's Knowledge Center Americas. "So of course this includes cast iron and steel, but you're also looking at metals that don't typically rust, such as stainless steel and most superalloys."

But looked at another way, the nonferrous group of materials includes aluminum, copper, brass, plastic, and composites, and anything not in this group can be classified as ferrous. But whether ferrous or nonferrous, they both contain a huge variety of materials that require a wide range of different design features, speeds and feeds, explains Schade.

A purist might argue that many aluminum alloys and even some coppers and bronzes are therefore ferrous because these also contain small amounts of iron. But that is likely an oversimplification. It isn't only whether iron is present: It's the amount of iron, notes Schade.

Nonferrous metals do not contain an iron base or significant amounts of iron at all. For example, 316 stainless steel contains roughly 62 to 72 percent iron; Inconel 718 is a nickel base, but still contains 17 percent iron and 6061-T6 aluminum only contains a maximum of .7 percent iron. This is why Schade says it's difficult to make sweeping statements about such a deeply technical topic.

"What's more relevant is identifying which tools work best for a given material, regardless of its nomenclature," says Schade.

Binky Sargent, manager of materials analysis at Kennametal, agrees. "Whether ferrous or nonferrous, 304 stainless or 6061-T6, the most important thing to consider is how the cutting tool interacts with the material," she says. "You need to know how the chip is formed and the most effective ways to remove it from the work zone, what effect the material's thermal and chemical properties will have on the tool, and the shape of the part feature relative to the shape and geometry of the cutter."

Essentially, proper tool selection depends on far more than the workpiece material's metallurgical classification.

> ## A Challenging Material to Cut: Carbon Fiber Reinforced Polymer
>
> Known by its acronym CFRP, this blend of carbon fibers and epoxy-like base material is both strong and lightweight, making it a favorite of aircraft and sporting goods manufacturers alike. Unfortunately, it can be ***pretty tough to machine***. Delamination is a common problem, as are spalling, splintering and uncut fibers. Cutting fluids are generally avoided with CFRP since some will swell up like a stiff sponge when wet, so dust is a concern. So is heat buildup in the workpiece during machining.
>
> The good news is that Kennametal, Seco and other cutting tool suppliers have developed specialty tools that eliminate much of CFRP's unpleasantness. Diamond-coated carbide "down-cut" router bits are one good choice. Take note: "Veined" or ***diamond-tipped drills and milling cutters*** are often needed for production applications. Either way, the tool must be very sharp and will most likely have a high-positive rake with generous clearance angles.
>
> "Look for a cutting tool with good edge strength and wear properties, but has the ability to take heat away from the process," says Seco's Hoefler. "That's why diamond is so commonly used, as it's an excellent heat dissipater. Here again, though, it's a good idea to work closely with a knowledgeable cutting tool supplier, as this is yet another area where the technology is constantly evolving."

Ferrous vs. Nonferrous Metals: Selecting the Right Cutting Tool

Kennametal and other cutting tool manufacturers avoid "ferrous vs. nonferrous," and instead base their material groupings on metallurgical characteristics such as hardness, strength, ductility, thermal conductivity and chemical composition. It's these attributes that determine which cutting tool is most effective at machining any given material, and how to best apply it. The following list describes each of Kennametal's categories, along with some basic guidelines on cutting tool selection:

Steel: P1 – P6

Low-carbon steels such as 1018 and A36 fall into the P1 category, while P6 includes PH (precipitation hardening) and 400-series stainless steels (440C, 15-5, and 17-4, to name a few). In between sit the tool steels (D2, S7), mold steels (P20), and various alloy steels (4340, 8620, etc.). Generally speaking, a positive rake, aluminum oxide coated carbide tool works well on the softer P1 and P2 metals, whereas one with greater edge preparation (think K-lands) and a more negative rake is preferred as hardness increases.

Stainless Steel: M1 – M3

Unlike the ferritic and martensitic stainless steels found in the P grouping, M1 and M2-type stainless steels are austenitic (meaning they have a face-centered cubic crystalline structure), while the duplex M3 steels (Nitronic is one) have a two-phase microstructure that includes ferrites, making them very tough. Stainless and duplex steels also contain at least 10.5 percent chromium, as well as nickel and other challenging elements. As a rule, use a positive rake CVD-coated tool with minimal edge prep, moderate feedrates, and lower depths of cut.

Need help with machining nickel? Read "5 Metal-Cutting Tips for Nickel-Based High-Temp Alloys."

Cast Iron: K1 – K3

Iron is found in everything from manhole covers, which use K1 or gray cast iron, to brake discs, that use CGI, or compacted graphite iron, which is a K2 metal, to the vises found on the shop's machining centers. Vises use a K3-grade ductile iron, which is also known by its trade name "Dura-Bar." All irons are short chipping and abrasive that make flat top (zero to negative rake) ceramic and PCBN cutting tools the first choice. CVD-coated carbide does a fine job on all but the hardest of irons.

Nonferrous: N1 – N7

As Kennametal's Schade points out, nonferrous is any material that does not contain iron—mostly. Designation N1 through N3 includes all aluminums from the ubiquitous 6061-T6 to the eutectic, and very abrasive, Al-12Si.

N4 signifies copper, brass and zinc-based alloys, which is a sizable list of largely free-machining metals. N5 though N7 contains everything from plastic and rubber to graphite and CFRP.

From a cutting tool perspective, most of these materials machine well with a high-positive, usually uncoated carbide or PCD, or polycrystalline diamond insert, although soft plastics and rubbers may cut best with a very sharp HSS tool bit.

Superalloys: S1 – S4

As the name implies, the S-series of high-temp alloys are among the most difficult of all materials to machine and include:

- S1: A286, which is iron-based or S1 alloy
- S2: Stellite that contains cobalt
- S3: Inconel 625 and Monel are superalloys that are high in nickel
- S4: Titanium such as Ti6Al-4V is the most common material

Long, stringy chips are the rule, as is depth-of-cut notching, work hardening- and built-up edge. Sharp, positive rake cutting tools are needed, along with slower cutting speeds and a rigid setup. For greater productivity, consider ***ceramic*** cutting tools, with the one exception being titanium, due to its chemical reactivity.

Hardened Materials: H1 – H4

Once tool steel, pH stainless and high carbon steels have been hardened through heat treatment, it's often necessary to switch from a carbide cutting tool to one made of ceramic or "PCBN," which stands for polycrystalline cubic boron nitride.

Depths of cut and cutting speeds must also be reduced, so as to mitigate the extreme wear resistance and abrasiveness of hardened H1 (up to 48 HRC) to H4 (greater than 60 HRC) materials. As with superalloys, the more rigid setup, the better.

Criteria for Cutting Tool Selection Similar Across Tooling Manufacturers

Brian Hoefler, corporate application engineer for ***Seco Tools*** and ***Sandvik Machining Solutions***, uses slightly different material descriptions than Kennametal, but the basic criteria for cutting tool selection is the same.

"Any material's machinability is largely dependent on its microstructure, thermal conductivity, carbon content, the presence of alloying elements like molybdenum and tungsten, and a whole host of other variables," says Hoefler.

At the end of the day, choosing the right tool typically comes down to what cutting tool material, geometry and coating is most effective at breaking the workpiece material's metallurgical bonds while withstanding the heat and abrasiveness generated during machining.

"When in doubt, communicate with a knowledgeable cutting tool supplier for help," says Hoefler. "No matter what you're cutting, chances are excellent that there's a productive, cost-effective solution available."

How well do you know the metal makeup of the materials you cut? Share with your peers.