CPM High Speed Steels

Since 1970, most of the more highly alloyed premium high speed steels have been produced by the CPM (Crucible Particle Metallurgy) process.

The fine structures that result from rapid solidification in the CPM process offer premium characteristics for both the manufacturers of cutting tools and their users. The more uniform distribution and the finer size of carbides in CPM steels are especially evident in comparisons with larger diameter bars of conventionally produced high speed steel, where carbide segregation is more of a problem. Thus, while the benefits pertain to cutters of all dimensions, they are more pronounced in larger tools.

There are four principal benefits of CPM high speed steels for tool users:

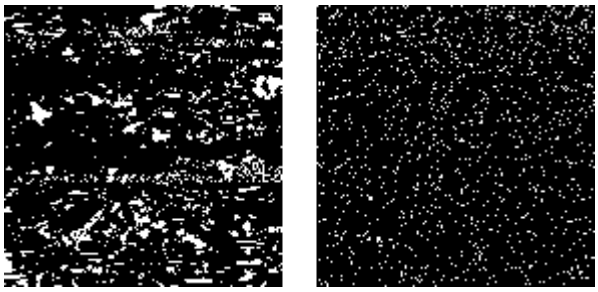
The primary benefit is the availability of higher alloy grades which cannot be manufactured by conventional steelmaking. These grades provide enhanced wear resistance and heat resistance for cutting tool applications. REX 20, REX 54, REX 76 and REX 121 are examples. These grades represent significant progress in the development of steels with unique characteristics. CPM Rex 20 equals or outperforms M42, yet is cobalt-free. CPM Rex 76 offers an excellent combination of high attainable hardness, toughness and wear resistance, and is an excellent substrate for advanced coatings such as TiAlN. Rex 121 has the highest attainable hardness and highest red hardness of any high speed steel.

Second, the increased toughness of CPM high speed steels not only provides greater resistance to breakage (particularly valuable in intermittent cut operations), but it also allows a tool to be hardened by 0.5 to 1.0 points higher on the Rockwell C scale without sacrificing toughness. Both longer tool life and higher cutting speeds can be realized.

Third, CPM offers improved grindability with no reduction in wear resistance of the tool. This means reduced grinding-wheel wear. Grinding can be done more quickly with less danger of damage to the cutter, and it leaves an edge that produces a smoother finish on the work piece.

Fourth, the greater consistency in heat treatment and uniformity of properties of CPM high speed steels increases the degree of predictability for scheduling tool changes. This factor is particularly advantageous in multi-spindle machines, where a single cutter failure affects several spindles and usually requires changing all cutters (including some that may have a lot of life left) for the sake of prudence.

Finer Carbide Size and Distribution



CONVENTIONAL HSS CPM

This illustration shows the key metallurgical characteristics responsible for the successful application of particle metallurgy products. Both microstructures are for 2" diameter AISI T15 - CPM on right and conventionally produced on the left (500X, longitudinal cross section).

Note the very fine and uniformly dispersed carbide distribution in CPM steels compared to the segregated distribution and broad size range of the carbides in the conventional product. The finer carbide structure in CPM also results in finer grain size control.

For the same reason the carbides are fine and uniformly distributed, so are any sulfides that are formed. At Crucible, we take advantage of this characteristic to re-sulfurize to high sulfur levels where enhanced machinability is required without significantly affecting the toughness properties. This could not be done with conventional ingot processing.

The differences in microstructural control between CPM and conventionally ingot-cast high alloy tool steels of the same composition can have a decisively beneficial influence on the steel's behavior in certain tool manufacturing operations as well as on tool performance. Specifically, these potential benefits include:

a) Better annealed machinability
b) More consistent and safer heat treat response
c) Significantly improved grindability
d) Good toughness characteristics
e) Larger size capability in full length bars

The High Speed Steel Comparagraph is a graphical presentation of the three properties usually considered when selecting a high speed steel for cutting tools - red hardness, wear resistance, and toughness.

At the bottom of the chart, we have grouped the high speed steels into four major categories - general purpose (e.g. M2), wear resistant (e.g. M3 and M4), cobalt-type (e.g. M35 and M42), and super high speed (e.g. Rex 20, Rex 45, Rex 54, T15, Rex 76, and Rex 121).

In general, red hardness increases with total alloy content and particularly with alloys responsible for high attainable hardness. There is a strong effect of

increasing cobalt content on heat treat response and temper resistance. Thus M2 with less than 20 percent total alloy content, no cobalt, and an attainable hardness of 64-66 HRC, is at the low end of the red hardness curve; whereas CPM Rex 121 with 37 percent total alloy content, 9 percent Co, and an attainable hardness of 70+ HRC is at the top of the curve.

Wear resistance is affected by the heat treated hardness, but more importantly it is a function of the amount and type of hard alloy carbide present in the structure of the material. Of the alloying elements generally found in high speed steels, vanadium forms the most wear resistance carbides followed in decreasing order of effectiveness by tungsten, molybdenum, and chromium. Thus, although wear resistance tends to increase with total alloy content and attainable hardness, there are notable peaks in the wear resistance curve at the high vanadium compositions, e.g. CPM M4, CPM Rex 54, CPM T15, CPM Rex 76, and CPM Rex 121.

Toughness generally decreases with increased alloy content, particularly for the high cobalt, higher attainable hardness materials. However, the CPM high speed steels are consistently tougher than their conventional counterparts. Thus, some of the higher alloy CPM-produced grades may be as tough as, or tougher than, lower alloy conventionally-produced grades. In fact, CPM M4 exhibits the best toughness properties of any high speed steel we currently produce, conventional or CPM. Combined with its excellent wear resistant properties and good grindability (comparable to conventional M2) CPM M4 represents the best high performance “general purpose” high speed steel on the market today.

In applications where customers have traditionally used conventional M2 or M3 (e.g. broaches, form tools, hobs, milling cutters, etc.), the trend is toward upgrading to CPM M4, which is the toughest high speed steel we produce and is surpassed in wear resistance only by CPM T15, Rex 76, and Rex 121. CPM M4 will even out wear M42 in applications where red hardness is not the controlling property.

In applications where it has been traditionally necessary to use a high cobalt material for red hardness, e.g. M42, upgrading can be accomplished by progressing from M42 to CPM Rex 20, CPM Rex 45, CPM Rex 54, CPM T15, CPM Rex 76 or CPM Rex 121. All six CPM high speed steels offer both excellent red hardness characteristics and very good wear resistance properties compared to M42.

The objective of any end user should be to get from the left hand side of this chart to the right hand side thereby upgrading the cutting tool performance, and reducing the overall tooling and equipment costs.