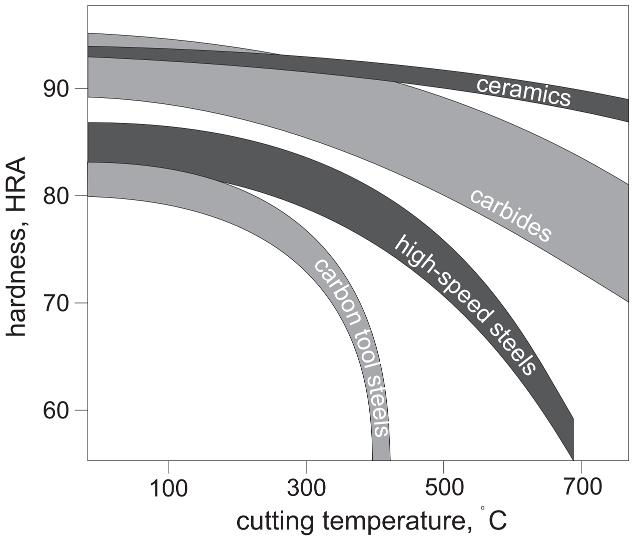
## 5.8 CUTTING TOOL MATERIALS

### *Requirements*

The cutting tool materials must possess a number of important properties to avoid excessive wear, fracture failure and high temperatures in cutting, The following characteristics are essencial for cutting materials to withstand the heavy conditions of the cutting process and to produce high quality and economical parts:

- *hardness* at elevated temperatures (so-called *hot hardness*) so that hardness and strength of the tool edge are maintained in high cutting temperatures:




Hot hardness for different tool materials

- *toughness*: ability of the material to absorb energy without failing. Cutting if often accompanied by impact forces especially if cutting is interrupted, and cutting tool may fail very soon if it is not strong enough.
- *wear resistance*: although there is a strong correlation between hot hardness and wear resistance, later depends on more than just hot hardness. Other important characteristics include surface finish on the tool, *chemical inertness* of the tool material with respect to the work material, and *thermal conductivity* of the tool material, which affects the maximum value of the cutting temperature at tool-chip interface.

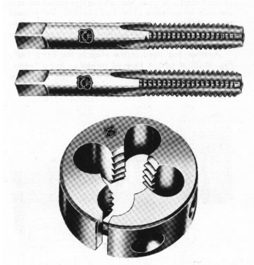
### *Cutting tool materials*

**Carbon Steels**

It is the oldest of tool material. The carbon content is 0.6~1.5% with small quantities of silicon, chromium, manganese, and vanadium to refine grain size. Maximum hardness is about HRC 62. This material has low wear resistance and low hot hardness. The use of these materials now is very limited.

**High-speed steel (HSS)**

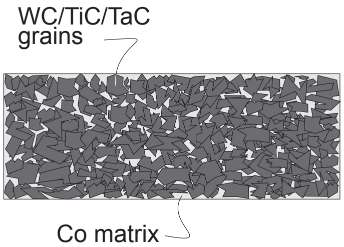
First produced in 1900s. They are highly alloyed with vanadium, cobalt, molybdenum, tungsten and chromium added to increase hot hardness and wear resistance. Can be hardened to various depths by appropriate heat treating up to cold hardness in the range of HRC 63-65. The cobalt component give the material a hot hardness value much greater than carbon steels.  The high toughness and good wear resistance make HSS suitable for all type of cutting tools with complex shapes for relatively low to medium cutting speeds. The most widely used tool material today for taps, drills, reamers, gear tools, end cutters, slitting, broaches, etc.



Thread tap and die made of high-speed steel

**Cemented Carbides**

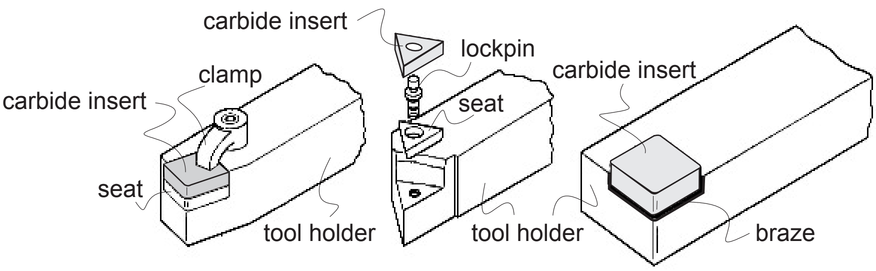
Introduced in the 1930s. These are the most important tool materials today because of their high hot hardness and wear resistance. The main disadvantage of cemented carbides is their low toughness. These materials are produced by powder metallurgy methods, sintering grains of *tungsten carbide* (WC) in a *cobalt* (Co) matrix (it provides toughness). There may be other carbides in the mixture, such as *titanium carbide* (TiC) and/or *tantalum carbide* (TaC) in addition to WC.




Microstructure of cemented carbides

Assortment of cemented carbide inserts for use by different cutting tools. Some of the inserts are coated with a very thin layer of wear-resistant material.

In spite of more traditional tool materials, cemented carbides are available as inserts produced by powder metalurgy process. Inserts are available in various shapes, and are usually *mechanically attached* by means of clamps to the tool holder, or *brazed* to the tool holder (see the figure in the next page). The clamping is preferred because after an cutting edge gets worn, the insert is *indexed* (rotated in the holder) for another cutting edge. When all cutting edges are worn, the insert is thrown away. The indexable carbide inserts are never reground. If the carbide insert is brazed to the tool holder, indexing is not available, and after reaching the wear criterion, the carbide insert is reground on a tool grinder.




(a) (b) (c)

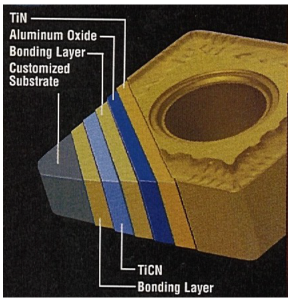
Methods of attaching carbide inserts to tool holder:
(a) clamping; (b) wing lockpins; and (c) brazing

ISO specifies three basic grades for cemented carbides according to use:

| SYMBOL | COMPOSITION | WORK MATERIAL | COLOUR† | DESIGNATION |
|---|---|---|---|---|
| P | WC + TiC | Low-carbon, stainless and other steels | Blue | P01, P10, ... P50 |
| M | WC + TiC + TaC | For all types of materials, especially difficult-to-cut materials | Yellow | M10, M20, ... M40 |
| K | WC | Cast iron, non-ferrous metals, non-metallic materials | Red | K01, K10, ... K40 |

† Colour of the tool holder for brazed cutting tools

One advance in cutting tool materials involves the application of a very thin coating (~ 10 μm) to a K-grade substrate, which is the toughest of all carbide grades. Coating may consists of one or more thin layers of wear-resistant material, such as *titanium carbide* (TiC), *titanium nitride* (TiN), *aluminum oxide* ($Al_2O_3$), and/or other, more advanced materials. Coating allows to increase significantly the cutting speed for the same tool life.




Structure of a multi-layer coated carbide insert

### Ceramics

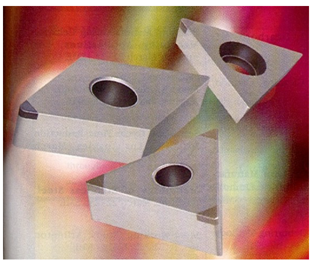
Ceramic materials are composed primarily of fine-grained, high-purity aluminum oxide ($Al_2O_3$), pressed and sintered with no binder. Two types are available:

- ❶ *white*, or *cold-pressed ceramics*, which consists of only $Al_2O_3$ cold pressed into inserts and sintered at high temperature.
- ❷ *black*, or *hot-pressed ceramics*, commonly known as *cermet* (from ceramics and metal). This material consists of 70% $Al_2O_3$ and 30% TiC.

Both materials have very high wear resistance but low toughness, therefore they are suitable only for continuous operations such as finishing turning of cast iron and steel at very high speeds. There is no occurrence of built-up edge, and coolants are not required.

### Cubic boron nitride (CBN) and synthetic diamonds

*Diamond* is the hardest substance ever known of all materials. It is used as a coating material in its polycrystalline form, or as a single-crystal diamond tool for special applications, such as mirror finishing of non-ferrous materials. Next to diamond, CBN is the hardest tool material. CBN is used mainly as coating material because it is very brittle. In spite of diamond, CBN is suitable for cutting ferrous materials.



Polycrystalline cubic boron nitride or synthetic diamond layer on a tungsten carbide insert