Workshop Tools

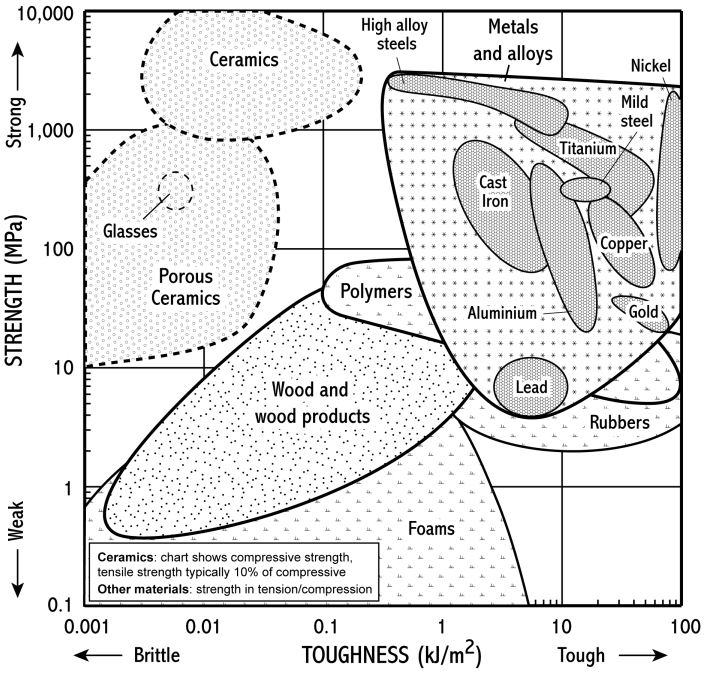
Tools lie at the heart of any workshop. Most are made of steel or cast iron, but in each case the alloy has been carefully chosen and the processing tailored to the application.

Strength, hardness and wear resistance.

The **strength** of a material is the load it can take (per unit area) before permanently deforming. For metals this is normally by yielding, which gives the values shown on the chart below. Ceramics have high failure strengths in compression and these are the values shown on the chart. In tension, ceramics fail by **fracture** and the strength is much lower (typically 10%).

The **hardness** of a material is related to its strength – hard materials are also strong materials. This is because hardness is really another measure of the resistance to permanent deformation, but for a small indent rather than the whole specimen.

The **resistance to wear** of a material is a difficult property to define. In practice it is found that harder materials have better wear resistance. We can therefore use the chart below to select materials which will have good wear resistance (they lie towards the top).



Question 1

Cast iron is hard and brittle, but easy to machine (because it contains flakes of graphite). Why is it used for tools such as vices, marking-out tables, and V-blocks?

Question

Try it yourself 1

Design a test to rank various materials in order of their wear resistance. Check to see that the materials that have better resistance to wear are also the stronger materials. *Tip*: use a very strong material to slide against your test materials.

Try it yourself

Drill bits & Cutting tools

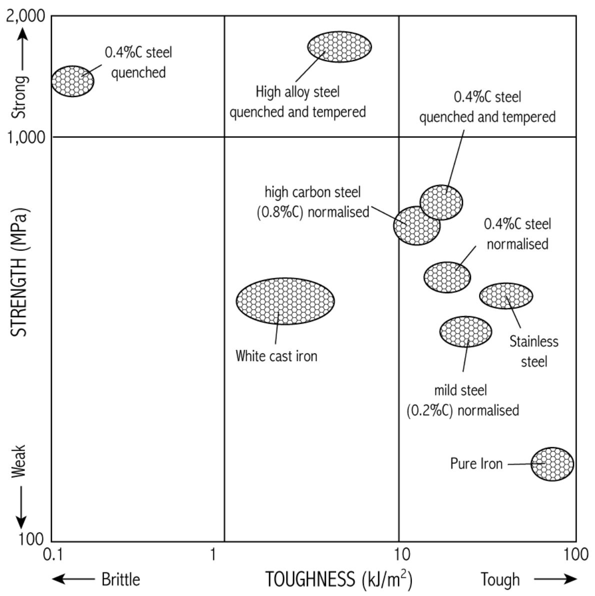
These are usually made of steel because they need to be tough. However, they also need excellent wear resistance so are often coated with hard ceramics such as titanium carbide (TiC), boron nitride (BN) or diamond. Because the coating is not very thick, the tools can have excellent wear properties without losing toughness.

Abrasive Cloths

Ceramics are ideally suited to this task being extremely hard and available in the form of fine grit. Typically glass and silicon carbide of varying grit sizes are available.

Grinding wheels

Because a grinding wheel is meant to remove thin layers of material from other components but not to wear much itself, it needs to be as hard as possible. Grinding wheels cannot just be surface coated (like drill bits) since when the coating has gone the wheel will wear rapidly. The answer is to embed fine bits of ceramic in a softer matrix – this gives the wheel good toughness but also good wear resistance throughout its life.



Hacksaw blades

Hacksaw blades experience large forces and quite high temperatures whilst cutting metals. As a result, the body of the blade needs to be tough (so it remains flexible) and the cutting teeth need to be hard (so they don't wear out). One way of achieving this is to use a high carbon steel (0.7-1.4%C). The blade is stamped and the teeth formed in the softer normalised condition. The teeth are then locally quenched & tempered to increase their hardness. You should be able to work out roughly where normalised and quenched & tempered high carbon steels will be on the selection chart above using the information opposite on the effect of alloying and heat treating steels.

Forged versus cast

Cast components often contain large crystal grains and it is difficult to obtain a uniform microstructure. This is due to the way crystals grow on cooling (as an example look at the ice crystals on a lolly stick).

In forged components, the plastic deformation introduces many crystal defects (called dislocations). This makes it harder to deform further (work-hardening), but also refines the microstructure making it more uniform. Because of this the mechanical performance of work-hardened materials is usually better than comparable cast items. Only materials that can accept significant elongations can be forged (see chart on the right).

Question 2

Spanners

Spanners often have the word 'forged' on them as a sign of quality. Why are forged spanners thought to be better than cast ones? Is this true?

Question

Carbon steels

Carbon atoms are small compared with iron atoms and fit in the gaps between them. This disrupts the iron crystal structure making it harder. Carbon also reacts with iron and other alloy elements to form hard particles, which further increase strength.

Steels which have been cooled slowly are called "normalised". As the strength-toughness chart (left) shows, increasing the level of carbon tends to increase strength at the cost of toughness – compare normalised 0.2, 0.4 and 0.8% C steel.

Heat treatment of steels

The properties of steels (and many other metal alloys) can be controlled by heat treatment. For carbon steels, quenching causes a hard, brittle microstructure to be formed. "Tempering" partly softens the steel again, decreasing the strength (and hardness) but recovering toughness – compare normalised, quenched, and quenched & tempered 0.4%C steel on the chart (left).

One major reason for alloying steel is to improve the effect of heat treatment – compare "high alloy" steel and 0.4% carbon steel (both quenched & tempered) on the chart.

Hammer

A good hammer must have a high strength body to ensure good life, but this must be achieved with sufficient toughness or else it could splinter, possibly causing injury. It also needs to be reasonably heavy! Carbon steels (e.g. 0.4%C) are used because they are relatively cheap. To get sufficient strength they are quenched. However the faces need to be tough so the hammer is then dipped in molten lead to achieve a good temper.