Buying tool steel - Mel Turcanik 10/9/09

Just so there is no misunderstanding, this is not intended to be a comprehensive treatise on steel, tools or metallurgy. While I have studied the subjects to some degree, and done some working with the materials, I'm certainly not an expert. I will leave that designation to the likes of Alan Lacer and Jerry Glaser. The purpose of this article is to give the novice some idea of how to purchase steel suitable for woodturning tools. I would strongly suggest looking at the articles in the *American Woodturner* Summer 2008 and Summer 2009 for more information about steel and sharpening. (See references)

Steel is defined as a generally hard, strong, durable, malleable alloy of iron and carbon, usually containing between 0.2 and 1.5 percent carbon, often with other constituents such as manganese, chromium, nickel, molybdenum, copper, tungsten, cobalt, or silicon, depending on the desired alloy properties. The other metals alloyed with steel change it's properties in a variety of ways and there are hundreds of different types of steel. Interestingly, iron with 2-4.5% carbon is called cast iron and is comparatively weak. A few tables regarding the types of steel:

Low Carbon Steel - 0.05 - 0.35% Carbon
Easy Machining And Forming
Comparatively Less Strength, Comparatively Less Hardness
Least Expensive

Medium Carbon Steel, 0.35 - 0.50% Carbon
Hard And Strong After Heat Treating: Medium Depth Of Hardness
More Expensive Than Low Carbon Steel

High Carbon Steel - 0.50 - 1.00% Carbon
Hard And Strong After Heat Treating: Depth Of Hardness Increases
More Expensive Than Low And Medium Carbon Steels

Alloy Elements and their Effect On Steel

Aluminum	Deoxidation - Ease of Nitriding
Boron	Hardenability
Carbon	Hardness - Strength - Wear
Chromium	Corrosion Resistance - Strength
Cobalt	Hardness - Wear
Columbium	Elimination Of Carbide Precipitation
Copper	Corrosion Resistance - Strength

Lead	Machinability
Manganese	Strength - Hardenability - More Response To Heat Treatment
Molybdenum	High Temperature Strength - Hardenability
Nickel	Toughness - Strength - Hardenability
Phosphorus	Strength
Silicon	Deoxidation - Hardenability
Sulfur	Machinability
Tellurium	Machinability
Titanium	Elimination Of Carbide Precipitation
Vanadium	Fine Grain - Toughness

The internal structure of steel changes with, not only the amount of carbon and other alloy materials, but the temperature the steel has been at and the time over which temperature has changed. This is complex stuff. Most people tend to think of metals as homogeneous materials with no internal structure, unlike wood that has a grain structure. Actually, steel has a grain structure based on microscopic layers, grains or crystals of carbon or other materials.

Focusing on steel used for tools, called, unimaginatively, "tool steel" there is a specific classification system not used for other steels:

Tool Steel Categories

Category	Description	Materials Designation
A	Air Hardening	A2, A3, A4, A5, A6
D	Oil or Air Hardening (High Carbon, High Chromium)	D1, D2, D3, D4, D5, & D7
H	Hot Working (Chromium, Tungsten, Molybdenum)	H10, H11, H12, H13, H14, H16, H19, H20, H21, H22, H23, H24, H25, H26, H27, H41, H42, & H43
L	Special Purpose (Low Alloy)	L2, L3, L6, & L7
M	High Speed (Molybdenum)	M1, M2, M3(I), M3(II), M4, M6, M7, M10, M15, M30, M33, M34, M36, M41, M42, M43, M44, M46, M47, & M50
O	Oil Hardening	O1, O2, O6, & O7
P	Mold Making	P2, P3, P4, P5, P6, P20, & P21
S	Shock Resisting	S1, S2, S5, & S7
T	High Speed (Tungsten)	T1, T2, T3, T4, T5, T6, T7, T8, T9, T15
W	Water Hardening	W1, W2, & W5

Out of this list, the tool steels we are most likely to use for woodturning are:
A, air hardening
O, oil hardening
W, water hardening

M, high speed molybdenum
T, high speed tungsten
The air, oil, or water refer to the proper quench material to allow the required timing for the cooling of the steel when hardening. If cooled too fast or slow the martensite won't form a fine grain structure. More on that later.

In the Lacer articles, he also mentions PM, powdered metal. This is a technology that compresses and fuses metal that has been powdered beforehand. It is a way to alloy metals that have different critical temperatures and might layer, precipitate, or otherwise not come together in a uniform way. (Gross simplification) PM also allows the manufacturer to create parts in molds that require little machining. A good thing since PM requires different machining technology than regular alloys. Likewise, CPM, crucible particle metallurgy is a proprietary powdered metal process patented by Crucible Materials Corporation. These processes create metal with very fine and uniform grain structure leading to greater strength without loss of hardness.

I mentioned that the internal structure of steel changes with temperature. Steel is allotropic. That means that it can exist in different physical forms without chemical changes. Water is the most familiar allotropic material, being either ice, water or water vapor. Unlike water, which has one fixed temperature for change of state, one of the critical or transformation points will change with the percentage of carbon in steel. At room temperature, iron is in the state called "ferrite." The lower critical point is about 1330 degrees F. Above 1600 degrees F. or so the iron becomes austenite. Between 2550 and 2800 degrees F. it changes to "delta," which becomes liquid above 2800 degrees F. Austenite is a solid solution. When the steel is heated to become austenite the carbon that was in the form of iron carbide or pearlite becomes dissolved in the iron. When this is cooled rapidly, it forms a new microstructure called martensite. This is much harder and has a higher tensile strength than steel with a pearlite microstructure. It also has a lot of internal stress which can make it quite brittle. Depending on the alloy and the carbon content, different temperatures and quench times and materials can produce either a coarse grain structure or a fine grain structure hence, oil, water or air hardening.. When buying tool steel, the vendor will specify the correct temperatures and quench times and materials for properly hardening the steel. Thickness of the metal is critical for both heating and cooling as there is a time lag as temperature changes move through the metal. The potential for stress build up must be considered. The rate of change in temperature is also critical during cooling and different cooling materials from lead to oil air or water to salt all have different rates of removing heat depending on the alloy and desired grain structure.

Once steel has been transformed to martensite, it is usually too brittle to be useful so it must be tempered, that is, softened and stress relieved, so that it can be tougher and not shatter or crack. Again, depending on the specific alloy, there is a specific temperature and cooling procedure to retain hardness and gain the toughness.

Usually these heating procedures are done in a furnace where you can control the temperature precisely. For us, we may be able to do an adequate job using oxide colors forming on the surface as an indicator of temperature and a torch for heat. In order to do that, the metal must be bare, preferably polished and free of any dirt or oil, including fingerprints. Of course, using a torch may not provide uniform heating throughout and so only the surface may be hardened. It's also important to realize that a grinder can raise the temperature of the steel enough to change the color and alter the hardness of the metal.

Hopefully, at this point I've been able to convey the complexity of steel technology. If we are going to make our own tools we need to get simple.

Tools for turning must be fairly tough since we are cutting materials that may include knots in very dense wood and the occasional nail or chuck jaw. They must also be hard so that they can be brought to a very sharp edge and retain it for the length of a turning session. Compared to machining iron and steel, wood is pretty soft and rarely provides the shock or heat buildup seen in metal working. So just about anything used to machine metal should work at least reasonably well for wood. But since we are always looking for the best solution, we generally go for the most tough and hardest metal we can afford and work with. High Speed steel, designed to machine metal with higher surface cutting speed and tolerate heat build up, fits the bill most of the time. In addition to the good hardness and toughness characteristics, it's upper critical temperature is quite high so that if we get a bit of color change while grinding, we haven't lost the hardness. If you see it blue, all you have to do is let it air cool and no damage is done. Quenching it in water could introduce stress that might make it crack.

So, the nice thing about high speed steel (HSS) is that we can grind it without worry and it comes already hardened and tempered properly if we get it as manufactured tool bits. By definition, HSS must resist softening at temperatures of 1000 degree F, which is a dull red, beyond blue.

Here's how to go about ordering steel blanks from MSC Industrial Supply or Enco. These are the two companies I use because they have a good selection of products and their prices are reasonable. Both have given me good service as well. MSC is geared mostly to the commercial market and has a $25 minimum order. They really aren't interested in the hobbyist but will sell to anyone with a company name.

In the Enco catalog, go to cutting tools, tool bits. In the MSC catalog go to HSS & cobalt end mills, saws & cutters, square and rectangular tool bits, and round tool bits. What we used at the last tool making meeting were square and round bits. These are used on metal lathes to turn steel or softer metals. The square ones seem to cost about double what a round one does. That's because the square is ground to perfect square dimensions and the end is finished as a cutter so that it can be put into a tool holder and cut metal right out of the box. The round ones don't have a cutting edge ground on them. Of course, if we are going to turn them into wood turning tools, it doesn't matter. We're going to grind the end anyway. What we are looking for is M-2 HSS (high speed steel with molybdenum.) It is also available with cobalt which makes it even harder, and about double the cost, but if M-2 is good enough to cut steel, it should be fine on any wood. The important thing to remember here is that when you buy a tool bit, it's already heat treated and ready to go.

For making tools that you will have to bend or cut extensively then heat treat at home, you will want water, oil or air hardening steel. This is found in the area of the Enco Catalog called "Components, Fasteners and Raw Materials." The MSC catalog has this under "band saw blades, flat stock, drill rod & raw materials." In this section you will find flat stock and drill rod in a wide range of technical specifications. In the Enco catalog at the beginning of the section there will be a chart with the alloy composition of the different steels and a heat treating chart with the necessary procedures. There is also a chart telling you what hardness you can expect when done. This information is listed above each different product in the MSC catalog. All I can say is, "Good luck!" Here you are getting into a realm beyond this article. Alan Lacer has done demonstrations of making a hook tool and this is an example of when you will be shopping for one of these other steels.

If you want to go on line to order, which is sometimes faster than the catalog, go to http://www1.mscdirect.com/cgi/nnsrhm or, http://www.use-enco.com/CGI/INSRHM

For the HSS bits on the Enco site, use the "Shop by Category" list, go to cutting tools, then select tool bits. Next select round or square and you will have a list to choose from. For the other tool steel, start by selecting "more" from the category list, go to components, fasteners and raw materials and select either drill rod or flat stock. You get squares by selecting a width and thickness that are the same. There is a neat selection thing that lets you pick each specification and then it gives you what is has with those specs. You have to have an idea of what you are looking for, or just noodle around with it and get an idea of what's available.

For the HSS bits on the MSC site, there's a menu on the left. Choose "end mills, saws, cutters and tool bits." That takes you to the same menu or index list in the catalog. Go to the same end mill etc. section and choose tool bits. Now you choose round or square and that takes you to a list that you can select from. You can also choose to see the whole catalog page which has technical information and the whole list of what's available. You can just page through the catalog on the computer and see the whole thing just like the paper version if you want. For the other tool steel, go back to the index list and choose "band saw blades, flat stock, drill rod & raw materials," same as in the catalog. If you choose drill rod, in addition to the oil, air and water hardening, you will also see HSS and other types of steel. Be aware that all of this needs to be heat treated before use. There is a reference table with the specifications for that in the catalog and it's referenced on the selection pages. If instead of drill rod you choose flat stock, you then have many choices. If you know what you are looking for, you will find it.

These sites also have those thin parting tool blades that we get under several different turners names. Check under tool bits and cut off blades.

I hope this has given you some more depth of information about the steel used for tools and how to get materials that will give you tools that would cost several times more if factory made. Be sure to check out the sharpening article in this summers American Woodturner.

References:

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http://www.alanlacer.com/ (hook tool & a lot of other cool stuff)