Tools Steels for Woodturning an Overview

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Introduction:

Woodworking, in all its forms, has several common attributes, skills and tools, as well as inspiration and vision. One thing that may seem obvious but is almost never verbalized is that the tools and skills we develop are all used to do one thing: cut wood. The translation of our inspiration into reality requires it. Yet it seems that the ability of a tool to cut wood well is an afterthought (at least in our current era). We assume that the tools we buy are ready to go to work making our dream come true. We replace our router bits and saw blades when they dull. If the initial cost is high enough we take them to someone to be re-sharpened. Those of us who pursue woodworking in its more traditional forms, i.e., hand tool work (such as traditional woodworking, woodcarving and woodturning), fit this second category. Good hand tools are expensive and the cost of having someone else sharpen them is also expensive in both the time it takes us away from our projects and the money it costs. This article is directed at the introduction to Steel, the basic material used for cutting tools, and the basic concepts and disciplines necessary to sharpen tools quickly and efficiently. Hopefully this will make your woodworking easier and more pleasurable, and as a byproduct, turn the task of sharpening from one of pain and hardship into a pleasurable pause in the process of turning your inspirations into reality.

Steel: A very short history.

From the stone knife to the scalpel man has searched the world for materials to make tools that cut. An old article from National Geographic that I read describes Obsidian as the material that makes the keenest cutting tool, showing a picture of a scalpel made from a chip of Obsidian for Ophthalmic surgery.

About 6000 years ago we see first appearance of iron based products. Most Iron objects were made from meteorites. There was even an iron dagger made from meteorite iron found on King Tut’s chest. The first step in the chain of discovery of working iron (and thus steel) was the process of smelting copper by ancient potters. Imagine their surprise when after firing pots adorned with malachite in an unusually hot furnace they found an ingot of pure copper in the bottom instead of a fired pot. Copper smelting requires temperatures of 1083 degrees C. This key discovery, that some stones could be changed into metal is the beginning of alchemy and the search to change one thing into another started. Next came bronze. The addition of tin in small amounts (5%-10%) made the resulting metal harder and castable. This quickly replaced copper as the go to metal for farming and fighting instruments. Thus the ancient metal smiths discovered that small amounts of certain “impurities” could enhance desirable qualities of metal

The Bronze Age and Iron Age overlap about 1000 years due to the inability to reach the smelting temperature for iron (1535 deg C). The ancients could reach temperatures of 1100 deg C which is hot enough to successfully cause reduction of hematite into iron bloom (a spongy iron filled with pockets of slag). By repeatedly heating (at approximately 800 deg C, the melting point of the slag) and hammering this bloom smiths were able to “wring” pure iron from the bloom creating “wrought” iron which has a carbon content of approximately 0.1%. If the reduction process was continued long enough carbon began to diffuse into the wrought iron which lowered its melting point enough to turn it into a liquid creating “cast” iron which has a carbon content of approximately 3% - 4%.. Cast iron was good for many things, but not for cutting tools. From here it was a short step to steel chemically speaking. To get there though, smiths had to learn a few more tricks. Learning how to increase the carbon content of wrought iron without turning it into cast iron, then quenching and tempering. Here (today) we come to the end of almost 10,000 years of mans ongoing quest for a good cutting tool!

The simplest form of high carbon steel contains just iron and carbon. Today's closest equivalent to the ancient metal smiths steel is W1 tool steel. It contains 1.05% carbon, 0.25% Manganese, and 0.20% Silicon. By the way these simplest forms of steel are capable of producing the keenest edges of all steels. Why you ask? Hint hint! Because the size of the crystal structure of the steel is the smallest. Adding alloying elements increases the size of the crystal structure making the cutting edge larger!

Steel: How it works.

Think of steel as a cake. The simplest recipe is the basis for all cakes. Adding flour, sugar, baking powder, baking soda, salt, eggs and vanilla produce the basic cake. Adding other ingredients produces different flavors of cake. Add too much or too little of one ingredient can ruin the cake. So it goes with steel

Let's get started. First we need to define some terms.

Critical temperature:	The temperature at which steel loses its structure and goes into solution. The crystal structure dissolves and the steel loses its magnetic properties. This means that the molecules are set free and cannot orient themselves to each other. In this state the steel is liquid in all but shape (this is also called the transformation temperature or theCurie poing or the).
Ferrite	A BCC crystal phase of steel before heat treating.
Cemmentite:	Fe3C (iron carbide).
Pearlite:	Alternating layered structure of Ferrite and cementite (the softest state of steel).
Austinite:	A large, coarse, and irregular grain structure (phase transformation) that occurs during heat treating when the crystal structure disolves. The elements are in solution. It is when steel becomes non-magnetic.
Quench:	The controlled removal of heat from the steel to change its crystal structure.
Martensite:	A body-centered-tetragonal crystal structure. This is the desired structure that steel turns into as the result of quenching.
Tempering:	The controlled remove of hardness to improve durability.
RHC:	Rockwell Hardness C scale. The hardness scale most commonly used for woodworking and cutlery steels. The scale ranges from 0 – 100, with 0 equating to water and 100 equating to diamond. Woodworking tools need to be at least RHC54 or above depending on the grade and application.

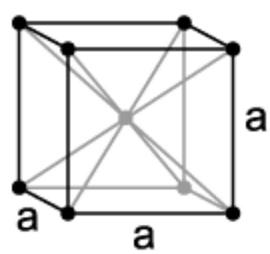
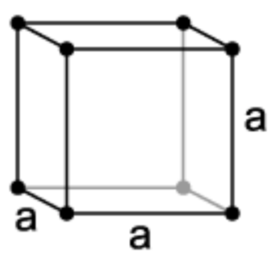
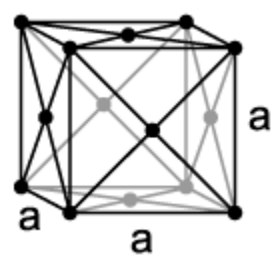
Let me first start with some steel background, using O1 tool steel as a starting point. O1 tool steel is considered a plain high carbon steel and is one of the most common types of tool steels. The addition of carbon in controlled amounts can change the characteristics dramatically. For instance, as the carbon content increases the melting point drops, the total hardness increases, tensile strength increases, wear-resistance increases and last but certainly not least is the ability to be heat-treatable.

(Note: Low carbon steels contain 0.03% - 0.30% carbon,
Medium carbon steels contain 0.35% - 0.55% carbon,
High carbon steels contain 0.60% - 1.5% carbon,
Ultra high carbon steels contain 1.6% - 2.5% carbon
At 3.0% steel turns into cast iron)

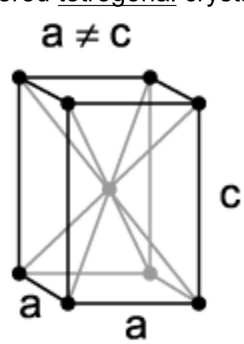
O1

Carbon	0.90%	See above.
Manganese	1.25%	Combines with residual Sulfur, reduces cracking during rolling mill operations.
Silicon	0.30%	Used to "kill" the steel or deoxidize the steel in the ladle.
Chromium	0.50%	The most common carbide formers.
Tungsten	0.50%	Added to improve hot-work characteristics (more on this later).

In its pre-heat treated or annealed state steel is made up of two structures; cementite and ferrite (pearlite is the layered structure of cementite and ferrite). To anneal steel, it is heated 50degF above the transformation temperature or critical temperature and then allowed to cool very slowly in the furnace. Annealing is a stress relieving operation. To heat-treat steel it must first be hardened. To harden steel, it is again heated 50degf above the transformation temperature and held there giving time for the carbides to dissolve(the structure of steel above the transformation temperature is called austenite). Once all the carbides are dissolved the steel is quenched. Quenching is the rapid cooling of steel. This rapid cooling prevents the austenite solution from disassociating back into cementite and ferrite. The rapid cooling traps or freezes Carbon atoms in the iron crystal matrix (body-centered-tetragonal crystal structure) called Martensite

body-centered cubic	**simple cubic**	**face-centered cubic**
		

body-centered tetregonal crystal structure



Martensite is hard and brittle with no ductility. Because of this characteristic the steel is carefully tempered (softened) to improve its durability. Tempering is done by soaking the steel in a furnace at a specific temperature below the transformation temperature. The actual temperature of the soak determines the final hardness of the steel. The tempering temperature for O1 starts at about 400degF for O1.

High Speed Steels are either Molybdenum M-series HSS, or Tungsten T-series HSS. Molybdenum is not as heavy yet forms equal amounts of carbides as Tungsten and as such has tended to displace Tungsten as the major alloy component. The largest advantage in moving to the HSS's is the high heat hardness and abrasion resistance that they characterize. The tempering chart for M2 starts at 975degF. Also the high Vanadium content improves the edge durability. Below are the most common HSS tool steels used in woodturning currently.

There are two accompanying documents of interest. The one describes the history and use of the Asea Stora process from Sweden and the second one describes the powder metallurgy process used at CPM steel. As you can see there is very little difference between the two processes as far as I can tell. Comparing the asp steels to the AISI steel recipes you can see that the major difference is the use of cobalt instead of vanadium for strength and wear-resistance. ASP 2030 closely resembles M4 otherwise and ASP 2060 uses about 10.5% Cobalt along with 6.4% Vanadium, excepting the inclusion of the Tungsten favorably matches the A11 in proportion (of course this is just a ball park kind of thing).

I have personally used M2 (from Henry Taylor and Crown), M4 (from Crown, Glazer and Oneway) and A11 from Glaser. I also own two tools a 3/8 gouge and a 1/2 skew in asp 2060. All in all I have probably used 20 gouges, scrapers and skews in M2, 6 - 10 gouges and skews in M4 and 4 A11 tools. So far I think the best bang for my buck has been the double-ended M4 gouges from Oneway. The Crown Pro-Pm tools are also a good buy. The Glaser A11 tools are really pricey, but I really like the 5/8 spindle gouge in M4 from Jerry. The M4 does outperform the M2, which is where I have seen the greatest cost/steel type advantage. I own two A11 skews, a 3/4 and a 1"(I am on my second one) and a 1/2 bowl gouge from Glaser which I have been comparing to the ASP 2060 1/2 skew and 3/8 gouge I got from Craft Supplies USA. The Crown Pro-PM tools at Woodcraft are pretty reasonable cost-wise. I have used them in a limited way during classes I teach at the local Woodcraft store. So far I still buy M2 tools quite frequently. My favorite M2 line is the Henry Taylor tools. These are the best buy particularly when it comes to scrapers. I have found that the more exotic steels don't burnish up a burr as well (they produce a brittle crumbly burr). So I have been staying with the M2 ones. One place I go for tool steel is ENCO. I purchase 1/4 round by 8" length tool bits that I use for all kinds of tools, like skews and scrapers and the like. I go to MSC for 3/8 rounds by 8" and 1/4 square by 8" in the WKE45 steel (this is a Swedish tool steel that MSC carries). I use the 3/8 round for my Bill Jones three corner tool and the square section pieces for scrapers and such. The ENCO rounds are less than 10 dollars and the MSC stuff is not much more as I remember.

There is no significant research going on to confirm or deny the claims of the tool manufacturers claims of edge retention for their tools. I did find one article which I will include with the upload to our website. That article showed some changes in edge retention for any alloy past M2, but not close to the manufacturer's claims. I will also include the other background material that I used for these two articles.

M2

Carbon	0.85%	See paragraph 2 above.
Manganese	0.30%	Combines with residual Sulfur, reduces cracking during rolling mill operations.
Silicon	0.30%	Used to "kill" the steel or deoxidize the steel in the ladle.
Chromium	4.15%	Is the most common carbide former.
Vanadium	1.95%	Added to promote a fine-grained composition and increase strength and wear-resistance.
Tungsten	6.40%	Added to improve hot-work characteristics.
Molybdenum	5.00%	Added to improve hot-work characteristics.
Sulfur	0.03%	The addition of Sulfur provides good grindability and improved machinability.

M4 (The first level where powder metallurgy technology is typically used)

Carbon	1.30%	(See above).
Manganese	0.30%	Combines with residual Sulfur, reduces cracking during rolling mill operations.
Silicon	0.30%	Used to "kill" the steel or deoxidize the steel in the ladle.
Chromium	4.00%	IS the most common carbide former.
Vanadium	4.00%	Added to promote a fine-grained composition and increase strength and wear-resistance.
Tungsten	5.50%	Added to improve hot-work characteristics.
Molybdenum	4.50%	Added to improve hot-work characteristics.

Sulfur	0.03%	The addition of Sulfur provides good grindability and improved machinability.

A11 (Also designated as V10)

Carbon	2.45%	See above.
Manganese	0.50%	Combines with residual Sulfur, reduces cracking during rolling mill operations.
Silicon	0.90%	Used to "kill" the steel or deoxidize the steel in the ladle.
Chromium	5.25%	Is the most common carbide former.
Vanadium	9.75%	Added to promote a fine-grained composition and increase strength and wear-resistance.
Tungsten	0.00%	Added to improve hot-work characteristics.
Molybdenum	1.30%	Added to improve hot-work characteristics.
Sulfur	0.07%	The addition of Sulfur provides good grindability and improved machinability.

V15

Carbon	3.40%	See paragraph 2 above.
Manganese	0.50%	Combines with residual Sulfur, reduces cracking during rolling mill operations.
Silicon	0.90%	Used to "kill" the steel or deoxidize the steel in the ladle.
Chromium	5.25%	The most common carbide former.
Vanadium	14.75%	Added to promote a fine-grained composition and increase strength and wear-resistance.
Tungsten	0.00%	Added to improve hot-work characteristics.
Molybdenum	1.30%	Added to improve hot-work characteristics.
Sulfur	0.07%	The addition of Sulfur provides good grindability and improved machinability.

ASP2030 (Asea Stora Process from Sweden)

Carbon	1.28%	See above.
Manganese	0.00%	Combines with residual Sulfur, reduces cracking during rolling mill operations.
Silicon	0.00%	Used to "kill" the steel or deoxidize the steel in the ladle.
Chromium	4.20%	The most common carbide former.
Vanadium	3.10%	Added to promote a fine-grained composition and increase strength and wear-resistance.
Tungsten	6.40%	Added to improve hot-work characteristics.
Molybdenum	5.00%	Added to improve hot-work characteristics.
Cobalt	8.50%	Added to increase strength and wear-resistance.

ASP2060 (Asea Stora Process from Sweden)

Carbon	2.30%	See above.
Manganese	0.00%	Combines with residual Sulfur, reduces cracking during rolling mill operations.
Silicon	0.00%	Used to "kill" the steel or deoxidize the steel in the ladle.
Chromium	4.00%	The most common carbide former.
Vanadium	6.50%	Added to promote a fine-grained composition and increase strength and wear-resistance.
Tungsten	6.50%	Added to improve hot-work characteristics.
Molybdenum	7.00%	Added to improve hot-work characteristics.
Cobalt	10.50%	Added to increase strength and wear-resistance.