Steel tool making and a Brief History
Dale Morse and Dave McKinnon

For our demonstration we will be using a piece of 4140 steel. This is classified as a medium carbon steel.

Figure 1 Forging the cutting end

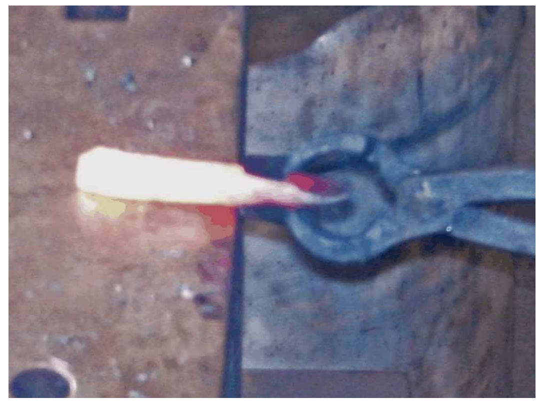


Figure 2 Crowning the striking end

In figure 1. we are forging the cutting end of a slot chisel. After we are satisfied with the shape of the cutting edge, we forge a crown on the striking end. A crown prevent us from striking a square edge on an angle, which of course would cause the tool to shoot out of our grip.

The next step is where it is important to know your material.
4140 steel in addition to iron has the following chemical components:

Carbon 0.40%
Silicon 0.25%
Manganese 0.85%
Chromium 1.00%
Molybdenum 0.25%

Since we know the type of steel we are using it is just a matter of looking up the parameters for hardening and tempering. It is an oil quench steel. That is a medium speed quench. Quench solutions run from salt water (very fast) through various oil quenches (medium) to air (slow). A quench medium is used to "lock" the crystalline structure of the steel in place. In high carbon steels locking them in by a water quench will cause them to become extremely brittle.

Figure 3 A pyrometer is used to insure that a heat of 830 to 880 degrees is reached

Figure 4 Grinding the cutting edge

Once the temperature is reached, the piece is quenched in an oil bath. We grind the cutting edge. For this slot punch we want a flat end about 1/8 of an inch in width. We also polish the sides removing scale so we can observe the colors run as we temper our piece.

Figure 5. No color yet

Figure 7 Dark blue on the right

Figure 7. Straw on the cutting edge

Controlled temperatures without a suitable oven are very difficult to achieve, especially in a coal forge. So to do this we take a block of steel and heat it to yellow hot. Then we lay our tool on it with the edge to be tempered away from the heat.

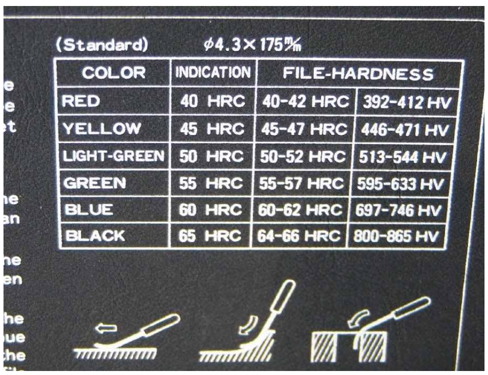
Fahrenheit	The Color of the Steel
2000°	Bright Yellow
1900°	Dark Yellow
1800°	Orange Yellow
1700°	Orange
1600°	Orange Red
1500°	Bright Red
1400°	Red
1300°	Medium Red
1200°	Dull Red
1100°	Slight Red
1000°	Very Slightly Red, Mostly Grey
800°	Dark Grey
575°	Blue
540°	Dark Purple
520°	Purple
500°	Brown/Purple
480°	Brown
465°	Dark Straw
445°	Light Straw
390°	Faint Straw

From slightly red-mostly grey to bright yellow (1000 to 2000 degrees Fahrenheit) are the visible light radiation colors you see when your are forging your piece. From faint straw to blue (390 to 575 degrees Fahrenheit) you observe when tempering steel. These colors are typical of unalloyed or low alloyed steel and will change with the steel's composition.

As the internal structure of the steel transforms the colors of the metal reflect it's temperature. This chart was from www.stormthecastle.com.

Figure 9 Vise as a heat sink

To stop the running of color, we place the tool in a vise which acts as a heat sink drawing the heat away from the tool. This method of arresting the tempering is less stressful on the steel then quenching it in water.



(Standard) φ4.3×175%

COLOR	INDICATION	FILE-HARDNESS	
RED	40 HRC	40-42 HRC	392-412 HV
YELLOW	45 HRC	45-47 HRC	446-471 HV
LIGHT-GREEN	50 HRC	50-52 HRC	513-544 HV
GREEN	55 HRC	55-57 HRC	595-633 HV
BLUE	60 HRC	60-62 HRC	697-746 HV
BLACK	65 HRC	64-66 HRC	800-865 HV

Figure 10 File calibrations

Figure 11 Calibrated files

Now using a set of calibrate files we can test of tool for hardness. We can establish the hardness to within 5 points Rockwell. Specification sheets give a Rockwell C hardness of 60 when oil quenched. Our tool measured between 45 and 50 on the Rockwell scale. So it is not at maximum hardness and should be less brittle on the working end.

Figure 12 The 40 HRC file slid over the metal

Figure 13 The light green file cut the metal

It is not clear when metallurgy became less alchemy and more science. Clearly, there was empirical experimentation and repetition of results. In some cases, there was obfuscation of the process to protect "trade secrets". Iron did not universally appear in 1200 BC with the ending of the bronze age. The terms copper, bronze and iron age refer to periods where items made of those material were predominant. At the height of the bronze age Aristotle noted that the Chalybeans threw a stone called primachos into the furnace allowing the Chalybeans to produce steel qualities in their iron. This sand used by the Chalybeans as flux had a high nickle content. This prevented their tools from rusting also as noted by Aristotle. It is the nickle content of their tools that has led some to assume they were meteor-iron derived tools. For 3,700 years the strategies for producing steeled edged tools and weapons were mostly rule of thumb. It is not surprising that by the time of St Patrick (circa 450 AD) that he wrote a prayer seeking protection from witches, druids, and smiths. He saw the metallurgy of his day as magic not science.

Let's skip ahead, the term "hardie hole" was in use by the 1860s, as we know, it refers to the square hole in the anvil. The word "hardie" derives from both German and French and references strength. So a hardie hole held a tool that was stronger than the metal being worked on. The tool was hardier. It need not necessarily be the tool steel we use today but a steel that had a higher carbon content. Remember, hot iron or steel is softer then cold. These hardie and other hand tools were probably made by a smith who observed that a particular piece of iron was stronger than the rest. He possibly saved that for his tools.

Today, metallurgy is a science. We know about the effects of heat and carbon on the crystalline structures in steel. We can be very scientific in our approach to tool making. BUT to even begin in this approach we have to know with what we are starting. Is that coil spring 1060, 1070, 1080, 1095, 5160 or 9260 or something else? How best can we use it? I read on a knife makers blog a question about using coil spring as a basis for a knife. The questioner was advised that the best he could do was collect his springs and take them to a scrap yard, sell them and use the money to buy a piece of known material. Of course, that makes sense for a knifemaker, who after producing knife (forging or stock removal) plans on sending it out for heat treatment.

So what should a blacksmith do? Always use known steel for tools? Buy a pyrometer? For at least 3000 of the 3700 years of blacksmithing there was no knowledge of the crystal structure of steel. The classical blacksmiths made tools, and crafted magnificent pieces. They used what they had and made do. I'm not saying you can't go out and purchase H1 or S7 and make fine tools but as hobbyists you don't need to. You do need to know how high in carbon steel your piece is. You can get some idea by looking at the sparks as you grind it. Compare them to the sparks from a known piece and estimate its composition. Then heat it to a critical temperature (a magnet will drop off) and depending on the estimated carbon, quench it in water or oil. Then temper your tool, and wear safety glasses (even when using store bought striking tools). Tools can be made from low carbon steel, if you're using them to work on hot metals, the tool will be harder. These won't last as long but they may get you through the day. If the tool does not work out, try again with a different type steel.