The Los Angeles Silhouette Club

Of Knives and Steel

By: Glen E. Fryxell

Reprinted with permission of
Glen E. Fryxell and GunBlast.com

The question gets asked all the time, "What's the best steel to make knives out of?". Well, the answer depends on what you want the knife to *do*...

Yeah, yeah, I know, you want the knife to *cut stuff*, but the key is to think about *how* the knife will be used, and what kind of wear and tear that use will put on the blade. For example, a general utility camp knife may have to slice up summer sausage for lunch one minute, and then chop away branches the next so that the tents can be erected; while a survival knife may be called upon for self-defense, and be subjected to violent stabbing and/or slashing maneuvers, and perhaps even be asked to block another blade. A filet knife needs to combine razor sharpness with flexibility in order to filet that tasty salmon you just caught, while a hunting/skinning knife needs to be able to take a fine edge and hold it throughout the entire gutting, skinning, packing and butchering chores, demanding more endurance than other applications. Blade shape is widely recognized as being very important to a knife's function, but it is also important to recognize that alloy and heat treatment are critical to the knife's function as well. Making a survival/combat knife out of a very hard, brittle alloy makes no sense as such blades can shatter readily when struck or stressed. Likewise, it makes little sense to make a hunting/skinning knife out of a softer, tougher steel that would require the successful hunter to stop and re-sharpen his knife every few minutes while field-dressing a game animal. How do the different alloys stack up for knife applications, and to what hardness are they typically heat treated? Let's review what the different components contribute to the final alloy, and then see which alloys are best suited for which jobs.

The most important constituent in steel is obviously iron (chemical symbol Fe). The bulk of all steel alloys is iron and it provides the matrix for all the other components to work, and it also provides the iron for the iron carbide phases that differentiate steel from iron. Next to iron, the most important constituent in steel is carbon (chemical symbol C). When iron ore is processed, it ends up with a significant amount of carbon (about 4%) in it as a result of the processing used to remove some of the other components of the raw ore. This 4% C alloy is used in making cast iron products. There are several iron carbide phases that are made when iron and carbon are mixed. The key phases responsible for the properties of steel are only accessible when the carbon content is below about 2%, so this cast iron alloy cannot be used directly to make steel, it is necessary to get rid of some of the carbon first. Typical steel alloys have somewhere between about 0.1% carbon to as much as 2% carbon. Alloys that have less than 0.5% carbon are called "low carbon steels", and alloys that have more than 0.5% carbon are called "high carbon steels". The amount of carbon in a steel alloy is important because it is the carbon that allows the alloy to be hardened through heat treatment, and more carbon allows for more hardness (up to a point). However, for simple iron/carbon alloys, increasing hardness also means increasing brittleness, and alloys above about 1.2% carbon can be unacceptably brittle for knife applications (depending on the heat treatment protocol used). Toughness is the ability of the blade to withstand stress without failure (brittle fracture, chipping, etc.), and generally speaking a softer alloys will provide better toughness than harder alloys. Overall, as a general statement, knife alloys will have 0.5% to 1.2% carbon in them (there are a few notable exceptions to this).

The next most important element in steel alloys would be chromium (chemical symbol Cr). The main thing that Cr contributes to steel alloys is corrosion resistance. Moderate Cr content of a few percent increases the corrosion resistance of the alloy, but does not make it a true stainless steel (these alloys are called "stain resistant"). For an alloy to be truly stainless it needs to have a Cr content of 13% or more, and the higher the Cr content the greater the corrosion resistance. It is important to recognize that stainless steels can still rust (especially if left in prolonged contact with blood), this corrosion resistance just means that they are less prone to rusting than are carbon tool steels. Cr also contributes to the "hardenability" of the alloy (by forming carbides), as well as its edge durability, but the main reason its added to the mix is to limit rusting.

Nickel (chemical symbol Ni) also contributes to the corrosion resistance of steel alloys, and it's not uncommon to see small amounts of Ni added to a stainless alloy for this reason.

Other metals from the middle of the periodic table of elements, like molybdenum (Mo), vanadium (V), manganese (Mn), and tungsten (W) are also commonly encountered in the steel alloys used to make knives. Like iron, these metals form carbides when mixed with carbon, and like the iron carbides, these metal carbides make the alloy harder. Each behaves a little bit differently and each contributes in it's own unique way, but the bottom line is that all contribute to the overall hardness of the alloy, as well as enhancing wear resistance. It is important to note that these components can increase the hardness of the alloy without necessarily increasing the brittleness of the alloy (particularly Mo). Mo and V are particularly valuable since they also contribute to the edge-holding durability of the knife, as well as the overall toughness of the alloy.

Silicon improves the strength and wear resistance of an alloy, but it is also added because it improves the properties of the steel during the manufacturing process.

So, in summary, carbon is what makes steel - *steel*, and somewhere between about 0.5% and 1.5% carbon makes for good blades (depending on the alloy and the application). 13% (or more) Cr makes a steel stainless, and helps to minimize corrosion issues, as well as helping hardenability. Ni also aids in corrosion resistance. Molybdenum helps to prevent brittleness, increases hardness, toughness and edge retention. Vanadium forms fine-grained carbides and enhances wear resistance, toughness and hardenability. Manganese contributes to hardenability and wear resistance, but also improves the properties of the steel during the manufacturing process (hot rolling etc.). Silicon improves strength and wear resistance, but it's like Mn in that it improves the properties of the steel during the manufacturing process. So the bottom line is somewhere around 1% C is good for a knife steel, 13% (or more) Cr makes it stainless, Mo and V aid edge retention, and small amounts of other elements like Mn and Si can also be beneficial.

Heat treating a steel alloy allows for the conversion of the various iron carbides formed in these alloys to one specific phase (martensite) that is harder and more desirable than the others. How this heat treatment is carried out depends on which alloy one is working with, and what final hardness one is aiming for. In a nutshell, the steel is heated to a specific temperature (commonly somewhere around 2000 degrees Fahrenheit for the stainless steels, lower for the carbon tool steels), held at that temperature for a certain period of time, and then taken through a very specific cooling process. For knife applications, a final hardness of somewhere in the range of 50-60 on the Rockwell C (Rc) scale is usually targeted. Blades that are hardened to over 60Rc are difficult to sharpen and tend to chip easily. Softer blades tend to be tougher and withstand stress and abuse better, but will generally have poorer edge retention. As with everything in life, compromises must be made, and the deciding factor is what kind of use the knife will be put to.

Tool Steels:

Historically, one of the traditional favorites for making knives is 1095, a simple tools steel that has 0.95% carbon in it, and 0.4% Mn. Knives made of 1095 take an edge very well, but they rust easily and are commonly coated with some sort of rust resistant coating (e.g. phosphate). It is reasonably tough (depending on what hardness it has been tempered to), but for better toughness lower carbon tools steels (e.g. 1060) are generally used. For those who have made knives from files, file steel is commonly 1095. 1095 can be heat treated up to about Rc 66, and then drawn down to the desired hardness. Ka-bar has been using 1095, heat treated to 56-58 Rc, for over half a century.

Simple water-quenching steels like W-1 and W-2 have 0.7-1.5% C, and less than 0.5% each, of Cr, Mn, Mo, Ni, Si tungsten and V, and are very similar to 1095 in terms of hardness, edge-holding and ease of rusting. Likewise, the simple oil quenching alloys like O-1 and O-2 (both of which contain 0.9% C, and 1.2% Mn; O-1 also has 0.5% Cr, 0.5% tungsten, 0.2% V) can also be heat treated up to about Rc 65, and then tempered down to the desired hardness. All of these steels rust easily.

A number of tool steels that were originally developed for more specialized applications have also been used in the knife-makers art. For example, L-6 is a band saw steel alloy that is composed of 0.7% C, 1.25-2.0% Ni, 0.6-1.2% Cr, 0.5% Mo, 0.25-0.8% Mn, 0.5% Si, 0.2-0.3% V. It has a reputation for having a good balance between workability, cost and good working toughness. L-6 can be heat treated to Rc 60, it is very tough and holds an edge very well, but the low Cr/Ni content leaves this alloy with poor corrosion resistance and it rusts easily. 5160H is a similar alloy (0.6% C, 0.6-1.0% Cr, 0.65-1.1% Mn, 0.15-0.35% Si) which can be hardened up to the mid-50s Rc and is respected for its toughness.

Bob Loveless reported that he made some very nice blades out of S5 (composed of 0.60% C, 0.85% Mn, 0.25% Cr, 0.30% Mo, 0.20% V, and 1.90% Si), that had very good toughness and edge holding properties, but that it was an unpredictable alloy that he never figured out -- about 1/3 of the blades would just shatter. Eventually he just walked away from S5; there was just too much frustration.

S7 is a somewhat similar alloy to S5, but with significantly more Cr and Mo, and less Si (S7 has 0.55% C, 0.70% Mn, 3.25% Cr, 1.40% Mo, 0.25% V, and 0.35% Si). S7 is becoming a popular steel for survival and combat knives as a result of its excellent toughness. While the Cr content makes this alloy somewhat rust resistant, S7 will definitely rust, and so these knives are commonly coated with some sort of rust resistant coating.

52100 is a somewhat harder, but nonetheless similar alloy, used to make ball bearings. 52100 is composed of 1.0% C, 1.5% Cr, 0.35% Mn and 0.35% Si. It requires some specialized (and involved) heat treating/quenching procedures, but can be heat treated up to a hardness of 67 Rc, and then drawn down to Rc 56-61, depending on the tempering temperature used. 52100 is well-liked among knife-makers for its toughness. This alloy is popular with certain makers for survival knives as a result of this trait (Swamp Rat Knife Works uses a variation of 52100 they call SR-101). These knives are also commonly coated with some sort of coating to prevent rusting.

Die Steels:

A-2 is a die steel, composed of 1.0% C, 5.25% Cr, 1.1% Mo, 0.6% Mn and 0.25 V, and makes a very good knife steel, with very good edge durability, and excellent toughness. It has some corrosion resistance but is definitely NOT stainless, and will rust. Note the higher carbon content along with more Mo (relative to the tools steels above), this is where A-2's highly regarded edge durability and toughness come from. A-2 can be heat treated up to Rc 64, and then is readily tempered down to a usable hardness of 60 Rc. Several knife makers (like **Bark River**) use A-2.

D-2 is another die steel, highly regarded for its excellent wear resistance. D-2 is almost (but not quite) a stainless steel, composed of 1.55% carbon, 11.5% Cr, 0.9% V, 0.8% Mo, 0.45 Si, and 0.35% Mn. Because of the high Cr content D-2 has good corrosion resistance, but it's not quite rust-proof. D-2 can be heat treated up to a hardness of 64 Rc, and then drawn down to 55 to 61 Rc, depending on the tempering temperature used (brittleness can be a problem if the alloy is left at 62-64 Rc). **Bob Dozier** is one of the notable knife makers who uses D-2 extensively in his hunting knives and Dozier's knives have an excellent reputation for taking and holding a fine edge (he heat treats them 60-61 Rc). My friend **Jim Taylor** has one of Dozier's knives and tells me that it will keep a fine edge through 3 or 4 deer without any need for re-sharpening.

Stainless steels:

Given the things that a sportsman's knife gets exposed to during routine usage (rain, sweat, blood, etc.) it's no surprise that stainless steels have gotten popular in order to limit corrosion (stainless steels will still rust, just not as easily as carbon steels). In fact, most knives made today are made with some sort of stainless steel. In this discussion, we'll start with the lower carbon classes of stainless and work our way up.

One of the more popular alloys in recent years for mass-produced knives is 420 High Carbon (HC), which is composed of about 0.5% C, 13.5% Cr, and 0.35-0.90% Mn. 420HC is used by a number of commercial knife manufacturers (e.g. **Gerber, Buck, Kershaw**, etc.), and is typically heat treated up to a hardness in the low 50s Rc. Knife manufacturers like this alloy because it's cheap, has excellent corrosion resistance properties, and is easy to grind (i.e. it isn't hard on tooling like some other alloys can be, this is a significant issue when mass producing thousands of blades and trying to keep costs affordable). It's easy to sharpen, and takes a decent edge, but edge retention isn't all that it could be and these blades typically need to be touched up regularly. 420HC makes a decent general purpose utility blade as it's easy to re-sharpen.

A similar alloy that one also finds in mass-produced knives is called 425 Modified, which is composed of about 0.5% C, 13.5% Cr, 1.0% Mo, 0.35% Mn, and 0.35% Si. As you can see from the C and Cr content this alloy is rather like 420HC, with the exception of the added Mo, which should give it somewhat better edge retention.

Swedish steel has been respected knife steel for many years. **Sandvik** makes a slightly harder, but similar (to 420HC) stainless alloy, called 12C27, that has been widely used in a number Scandinavian knives. 12C27 contains 0.65% C, 13.5% Cr, and 0.35% Mn. Alloys such as this are commonly heat treated to the mid to upper 50s Rc and have excellent toughness. 12C27 has a reputation for being a very "clean" alloy (i.e. consistent composition, with few impurities).

Perhaps the most commonly encountered stainless steel in commercial knife making today is the 440 class of alloys. This class is composed of three different alloys, 440A, 440B and 440C, all of which have very high Cr content (and hence corrosion resistance). 440A is the softest of this series, and is composed of about 0.55% C, 17% Cr, 1.0% Mn, 0.75% Mo, and 1.0% Si. It is used by several knife manufacturers and is commonly heat treated to the mid to upper 50s Rc. 440B is used by **Randall** to make their stainless knives, and it is composed of about 0.85% C, 17% Cr, 1.00% Mn, 0.75% Mo, 0.75%, and 1.0%

Si. The higher carbon content of 440B allows it to be heat treated up to Rc 59-60, if so desired. Of the three 440 alloys, 440C is arguably the best knife steel, both in terms of edge-holding ability and in terms of corrosion resistance. 440C contains about 1.1% C, 18% Cr, 1.0% Mn, and 1.0% Mo. The higher carbon content allows this alloy to be heat treated as high as 61 Rc (typically only taken up to about 58-60), and the very high Cr content gives 440C the best corrosion resistance of any of the typical knife steels. 440C is a very popular knife steel because it is widely available, has excellent corrosion resistance, is fairly easy to grind and takes a good edge. Edge retention is pretty good (although some have criticized 440C for not holding up under hard use).

A similar group of alloys has come over in recent years from Japan. AUS6, AUS8 and AUS10 have been compared (approximately) to 440A, 440B and 440C. AUS6 is the softer of these alloys and contains about 0.6% C, 14%Cr, 1.0% Mn, 1.0% Si, 0.49% Ni, and .25% V (there is also a variation on this alloy called AUS 6A that has 1.2% Mo in place of the V). AUS6 is typically heat treated to the mid 50s Rc, and it should have good toughness. AUS8 has gotten to be very popular lately and is being used by a number of knife manufacturers (**Cold Steel, Spyderco, Kershaw, SOG** and many others). AUS8 contains 0.75% C, 14% Cr, 1.0% Mn, 1.0% Si, 0.49% Ni, and 0.25%V (there is a variation on this alloy too, called AUS8A that contains 0.95% C, 14% Cr, 1.0% Mn, 1.0% Si, 0.50% Ni, 0.20% Mo, 0.15% V, 0.40% W, which should be harder and have better edge retention). AUS8 is generally heat treated up to 58-59 Rc and will take an excellent edge. Edge retention is good, but not as good as some of the higher grades of stainless (see below). AUS10 is a harder alloy that has been compared to 440C. AUS10 contains 1.10% C, 14% Cr, 0.50% Mn, 0.30% Mo, 0.49% Ni, 0.27% V. AUS10 doesn't seem to be very widely used at the moment (perhaps because it's competing head-to-head with 440C?), but it looks to be an excellent knife steel nonetheless.

In 1972, a new crucible steel was brought to market that was called 154CM. Bob Loveless was one of the first to use it to make knives, and he liked what this steel gave him and he gave it high marks. 154 CM contains 1.0% C, 14% Cr, 4.0% Mo, 0.6% Mn, and 0.25% Si (note the unusually high Mo content of 154CM; Mo is a key component in alloys used for high speed tooling and contributes wear resistance and durability to the alloy). Loveless made knives out of this alloy for many years, and this alloy helped establish Loveless' reputation as a knife maker. 154CM is now widely used by a number of custom knife makers, in top-quality hunting knives. It is generally heat treated up to about Rc 59-60, and will take an outstanding edge. Edge durability is reported to be excellent.

Japan responded to 154CM with an alloy that they called ATS34, intended to capture the same strengths as 154CM. ATS34 contains 1.04% C, 13.9% Cr, 3.55% Mo, 0.4% Mn, 0.28% Si, and is reputed to be a more uniform and "cleaner" alloy than 154CM (once again, note the high Mo content). Many knife makers (both commercial manufacturers and custom knife makers, Bob Loveless included) went over to using ATS34 as their preferred blade steel after it was introduced to the market. Like 154CM, ATS34 can be heat treated to 59-60 Rc, it takes an excellent edge and has excellent edge durability. Top-quality knives (and knife blanks) made from ATS34 are available from many sources.

Recently, a new alloy has come on the scene, one whose properties are sufficiently appealing that it has lured a few of these knife makers (including Loveless) away from ATS34. This new alloy is called BG-42, which is composed of 1.12% C, 14.5% Cr, 4.0% Mo, 1.2% V, 0.5% Mn, 0.3% Si. Note the BG-42 basically has more of everything than does ATS34 -- most notably more carbon, more chromium, more molybdenum and more vanadium (the fine-grained vanadium carbides add another element of durability to the alloy). Given this composition, one might expect it heat treat easily up to Rc 60, to take an excellent edge, and to hold it for a long time, and indeed it does. There aren't that many people using BG-42 at the moment, but I suspect that that will change in the coming years. It is an excellent knife steel.

A similar high carbon stainless that has gotten to be rather popular recently is CPM S30V. This alloy is composed of 1.45% C, 14% Cr, 2.0% Mo, 4.0% V, 0.40% Mn, and 0.40% Si (note the high carbon content, and while the Mo is lower than ATS 34, it is still pretty high, and is made up for by the unusually high vanadium content). S30V is designed to offer an optimum combination of toughness, wear resistance and corrosion resistance. This alloy is processed differently than typical steel alloys, resulting in a finer grain size and a more uniform distribution of the alloying elements, resulting in the greater toughness and wear resistance. S30V was specially formulated to promote the formation of vanadium carbides, which are harder and more effective than chromium carbides in providing wear resistance. S30V is usually heat treated to 58-61 Rc, and is reputed to have better toughness than highly regarded steels like 440C and D2, and is said to have better edge-holding capability than 440C. S30V is a hard, wear-resistant steel used by knife makers like **Spyderco, Benchmade**, and others.

Conclusions:

So which alloy makes the best knives? Well, that depends on what you want the knife to do. It also depends on what your taste in steel is like. The following discussion is one interpretation of how these alloys are suited for the different tasks that a knife is asked to do. Others might see things a little differently, but this can serve as a useful starting point.

The survival/combat knife needs toughness, and cannot tolerate brittleness, and so those knives tend to be made from alloys with intermediate carbon content (generally 0.6 to 0.8%), and heat treated to more moderate hardness (mid 50s Rc), as this is most conducive to blade toughness. Corrosion resistance is important since one never knows what kind of weather one might be up against (or for how long) in a survival situation, so some sort of corrosion resistant coating (and there are a number of very good ones out there) or stainless alloy are popular options for these knives. Since a corrosion resistant coating can also dull the glare of a polished blade, these are particularly popular in survival/combat knives. Alloys that fit well in this niche include S7, 52100, and 5160. A-2 and 1095 are also highly regarded in this application, in spite of their higher carbon content (tempered down to 56 or so). Toughness is a key concept for knives in this category.

Filet knives have similar needs, but for very different reasons. A filet knife needs to be flexible and does not tolerate brittleness very well, so once again toughness is a key attribute. Carbon content once again tends to be in the intermediate range (0.6% to 0.8%), since more carbon might lead to unacceptable brittleness. Filet knives tend to be heat treated tends in the mid 50s Rc to provide a good compromise between toughness and the ability to take a fine edge (the narrow blade profile on most filet knives makes them easy to re-sharpen quickly, so edge retention isn't generally a concern). Filet knives will get wet repeatedly (as well as bloody) in the course of their duties, so stainless alloys are a real plus here. Sandvik's 12C27 is an excellent fit for this category, as are 440A and AUS6.

The general utility camp knife needs to be sort of "jack of all trades". The blade needs to be moderately hard to be able to take a good edge, but it must also be tough enough to withstand light chopping. This set of demands suggests an alloy with moderately high carbon content (around 0.8 to 1.1%), heat treated to Rc 56-58. A traditional favorite for this application is good ol' 1095 (just make sure to maintain it and don't let it rust), and many folks would tell you that there's no better camp knife than a **Kabar**. A-2 is also highly regarded in this role. These days, one tends to see more stainless alloys in this application, and 440C makes a very useful camp knife, as does AUS8. S30V would also make a dandy camp knife.

A hunting/skinning knife needs to take a fine edge and hold it throughout the gutting/skinning/butchering chores. Blade hardness and edge durability are the key parameters here, so high carbon content (preferably over 1%) is called for, and high molybdenum content (2% or more) helps to hold the edge (and added vanadium is also a plus). Blood is three times as salty as seawater and can corrode knife steel very rapidly, so corrosion resistance is particularly valuable for a hunting/skinning knife, making high chromium stainless alloys are very useful here (and added Ni doesn't hurt any). These knives are generally heat treated up to about 60 Rc. Alloys that are particularly well suited to this application include S30V, 154CM, ATS34, and BG-42.

So which steel alloy is best for making knives? You tell me -- what do you want the knife to do?

- Glen E. Fryxell

The LASC Front Page   Index to all LASC Articles

Glen E. Fryxell Article Index