Stainless steel 420 440 quality of knives hardness of blades study

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As we inaugurate a new monthly feature devoted to the age old study of blades and bladecraft, it's only proper that we begin with a survey of the steels used in modern blades. It's a confusing and sometimes daunting topic. Many publications and manufacturers reference different types of steels when discussing a blade's construction and properties without offering an explanation as to the merits and detriments of a particular type of steel. It's almost as if the writers anticipate a thorough engineering background and knowledge on the part of the reader. Rather than assume that everyone is an expert on everything, we'd rather present an up front survey of the materials and technologies involved, and one that will be referred to in many articles to come. For the basis of this article, we've adopted much of Joe Talmadge's excellent FAQ. Additional data has been gathered from a variety of steel industry and knife making sources. We hope that you find this introduction as useful and informative as we did while writing it.

It's important to bear in mind is that the choice of blade steel is only one component in how a knife performs. One must consider the blade's intended use and match the characteristics to that use. Hence, factors such as blade profile are important; a tanto isn't the best choice to skin a deer, for example. But perhaps most important characteristic is the heat treatment. A good solid heat treatment on a lesser steel will often result in a blade that outperforms a better steel with inferior heat treatment. Bad heat treatment can cause a stainless steel to lose some of its stainless properties, or cause a tough steel to become brittle. Unfortunately, of the three most important properties (blade profile, steel type, heat treatment), heat treatment is the one that is impossible to assess by eye, and as a result excessive attention is sometimes paid to the other two.

Again, the blade's intended use is of paramount importance. Many of the cognoscenti deride 440A stainless steel, but there are few better materials for a marine or wet weather blade. Properly heat treated 5160 is wonderfully tough, but if the application is skinning deer, the edge holding qualities of 52100 are probably more important.

STEEL ALLOYS

At its most basic, steel is iron with carbon in it. Other alloying metals are added to bring out different characteristics in the steel. Here are the important steel alloy materials in alphabetical order, and some sample steels that contain those alloys:

Carbon: Present in all steels, it is the most important hardening element. Also increases the strength of the steel. Knife grade steel should usually have greater than 0.5% carbon, which makes it "high carbon" steel.

Chromium: Added for wear resistance, hardenability, and (most importantly) for corrosion resistance. A steel with at least 13% chromium is classified as a "stainless" steel. Despite the name, all steel can rust if not maintained properly.

Manganese: An important element, manganese aids the grain structure, and contributes to hardenability. Also strength & wear resistance. Improves the steel (e.g., deoxidizes) during the steel's manufacturing (hot working and rolling). Present in most cutlery steel except for A-2, L-6, and CPM 420V.

Molybdenum: A carbide former, molybdenum prevents brittleness and maintains the steel's strength at high temperatures. It is present in many steels, and air hardening steels (e.g., A-2, ATS-34) always have 1% or more molybdenum -- molybdenum is what gives those steels the ability to harden in air.

Nickel: Used for strength, corrosion resistance, and toughness. Present in L-6 and AUS-6 and AUS-8.

Silicon: Contributes to strength. Like manganese, it makes the steel more sound while it's being manufactured.

Tungsten: Increases wear resistance. When combined properly with chromium or molybdenum, tungsten will make the steel into a high speed steel. The high speed steel M-2 has a high amount of tungsten.

Vanadium: Contributes to wear resistance and hardenability. A carbide former that helps produce fine-grained steel. A number of steels have vanadium, but M-2, Vascowear, and CPM T440V and 420V (in order of increasing amounts) have high amounts of vanadium. BG-42's biggest difference with ATS-34 is the addition of vanadium.

CARBON AND ALLOY (NON-STAINLESS)

These steels are the steels most often forged. Stainless steels can be forged but it is very difficult. In addition, carbon steels can be differentially tempered, to give a hard edge holding cutting edge and a tough springy back. Stainless steels are not differentially tempered. Of course, carbon steels will rust faster than stainless steels, to varying degrees. Carbon steels are also often a little bit less of a crap shoot than stainless steels -- all of the steels named below are fine performers when heat treated properly.

In the American Iron and Steel Institute (AISI) steel designation system, 10xx is carbon steel, any other steels are alloy steels. For example, the 50xx series are chromium steels.

In the Society of Automotive Engineers (SAE) designation system, steels with letter designations (e.g., W-2, A-2) are tool steels.

There is an American Society for Metals (ASM) classification system as well, but it isn't seen often in the discussion of cutlery steels, so I'll ignore it for now.

Often, the last numbers in the name of a steel are fairly close to the steel's carbon content. So 1095 is ~.95% carbon. 52100 is ~1.0% carbon. 5160 is ~.60% carbon.

O-1

(Note: the accompanying tables show standard alloy compositions by percentages of alloyed elements - the primary (and assumed) component in all steels is iron)

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
0.90	1.60	0.00	0.50	0.00	0.00	0.00	0.50	0.00

This is an oil hardening (i.e., quenched in oil when removed from the forge) steel very popular with forgers, as it has the reputation for being "forgiving". It is an excellent steel, that takes and holds an edge superbly, and is very tough. It rusts easily, however. Randall Knives uses O-1, so does Mad Dog.

W-2

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
1.00	0.35	0.30	0.00	0.00	0.00	0.20	0.00	0.00

A water hardening steel, W-2 is reasonably tough and holds an edge well, due to its 0.2% vanadium content. Most files are made from W-1, which is the same as W-2 except for the vanadium content (W-1 has no vanadium).

W-1

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
1.00	0.35	0.30	0.00	0.00	0.00	0.00	0.00	0.00

See W-2

The 10-series -- 1095 (and 1084, 1070, 1060, 1050, etc.) 1095 as an example

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
0.95	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Many of the 10-series steels are used for cutlery, though 1095 is the most popular for knives. When taken in order from 1095-1050, the steel goes from more carbon to less, from better edge holding to less edge holding, and tough to tougher to toughest. As such, 1060 and 1050 are often used for swords. For knives, 1095 is sort of the "standard" carbon steel, not too expensive and performs well. It is reasonably tough and holds an edge very well, though without care it oxidizes (rusts) easily. This is a simple steel, which contains only two alloying elements: 0.95% carbon and 0.4% manganese. The various Ka-Bars are usually 1095 with a protective black coating.

Carbon V (data for 50100B listed)

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt

0.95	0.45	0.00	0.45	0.00	0.00	0.20	0.00	0.00

Carbon V is a trademarked term by Cold Steel, and as such is not necessarily one particular kind of steel; rather, it describes whatever steel Cold Steel happens to be using at that time, and there is an indication they do change steels from time to time. Carbon V performs roughly between 1095-ish and O-1-ish, and rusts like O-1 as well. There have been rumors that Carbon V is O-1 or 1095. Numerous industry insiders insist it is 0170-6. Some spark tests seem to point the finger at 50100-B. Since 50100-B and 0170-6 are the same steel (see below), this is likely the current Carbon V.

0170-6 - 50100-B

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
0.95	0.45	0.00	0.45	0.00	0.00	0.20	0.00	0.00

These are different designations for the same steel: 0170-6 is the steel makers classification, 50100-B is the AISI designation. A good chrome- vanadium steel that is somewhat similar to O-1, but much less expensive. The now defunct Blackjack made several knives from O170-6,and Carbon V may be 0170-6. 50100 is basically 52100 with about 1/3 the chromium of 52100, and the B in 50100-B indicates that the steel has been modified with vanadium, making this a chrome-vanadium steel.

A-2

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
1.00	0.45	0.00	5.00	0.00	0.00	0.25	0.00	0.00

An excellent air hardening tool steel, it is known for its great toughness and good edge holding. As an air hardening steel, so don't expect it to be differentially tempered. Its outstanding toughness makes it a frequent choice for combat knives. Chris Reeve and Phil Hartsfield both use A-2, and Blackjack made a few models from A-2.

L-6

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
0.70	0.45	0.00	0.75	1.50	0.00	0.00	0.00	0.00

A band saw steel that is very tough and holds an edge well, but rusts easily. It is, like O-1, a forgiving steel for the forger. If you're willing to put up with the maintenance, this may be one of the very best steels available for cutlery, especially where toughness is desired.

M-2

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
0.95	0.45	0.00	0.45	0.00	0.00	0.20	0.00	0.00

A "high speed steel", it can hold its temper even at very high temperatures, and as such is used in industry for high heat cutting jobs. It is an excellent edge holder. It is tough but not as tough as some of the toughest steels in this section; however, it will still be tougher than the stainless steels and hold an edge better. It rusts easily. Benchmade uses M-2 in one of their AFCK variations.

5160

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
0.60	0.80	0.00	0.80	0.00	0.00	0.00	0.00	0.00

A steel popular with forgers, it is extremely popular now and a very high end steel. It is essentially a simple spring steel with chromium added for hardenability. It has good edge holding, but is known especially for its outstanding toughness (like L-6). Often used for swords (hardened in the low 50s Rc) because of its toughness, and is also used for hard use knives (hardened up near the 60s Rc).

52100

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
1.10	0.35	0.30	1.45	0.00	0.00	0.00	0.00	0.00

A ball bearing steel, and as such is only used by forgers. It is similar to 5160 (though it has around 1% carbon vs. 5160 ~.60%) and more chromium, but holds an edge better. It is less tough than 5160 however. It is used often for hunting knives and other knives where the user is willing to trade off a little of 5160's toughness for better edge holding.

D-2

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
1.50	0.40	0.00	12.00	0.00	0.80	0.90	0.00	0.00

D-2 is sometimes called a "semi stainless". It has a fairly high chrome content (12%), but not high enough to classify it as stainless. It is more stain resistant than the carbon steels mentioned above, however. It has excellent edge holding, but may be a little less tough than some of the steels mentioned above. And it does not take a beautiful finish. Bob Dozier uses D-2.

Vascowear

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
1.12	0.30	1.20	7.75	0.00	1.60	2.40	1.10	0.00

A very hard to find steel, with a high vanadium content. It is extremely difficult to work and very wear resistant. It is out of production.

STAINLESS STEELS

Remember that all steels can rust. But the following steels, by virtue of their greater than 13% chromium, have much more rust resistance than the above steels. It should be pointed out that there doesn't appear to be consensus on what percent of chromium is needed for a steel to be considered stainless. In the cutlery industry, the de-facto standard is 13%, but the ASM Metals Handbooks says "greater than 10%", and other books cite other numbers. In addition, the alloying elements have a strong influence on the amount of chromium needed; lower chromium with the right alloying elements can still have "stainless" performance.

420

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
0.15 - 0.40	0.23	0.21	12.2	0.00	0.00	0.00	0.00	0.00

Lower carbon content (less than 0.5%) than the 440 series makes this steel extremely soft, and it doesn't hold an edge well. It is used often for diving knives, as it is extremely stain resistant. Also used often for very inexpensive knives. Outside salt water use, it is too soft to be a good choice for a utility knife.

440 A - 440 B - 440C (data for 440C listed)

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
1.20	1.00	1.00	18.00	0.00	0.75	0.00	0.00	0.00

The carbon content (and hardenability) of this stainless steel goes up in order from A (.75%) to B (.9%) to C (1.2%). 440C is an excellent, high end stainless steel, usually hardened to around 56-58 Rc. All three resist rust well, with 440A being the most rust resistant, and 440C the least. The SOG Seal 2000 is 440A, and Randall uses 440B for their stainless knives. 440C is fairly ubiquitous, and is generally considered the penultimate general- use stainless (with ATS-34 being the ultimate). If your knife is marked with just "440", it is probably the less expensive 440A; if a manufacturer had used the more expensive 440C, he'd want to advertise that. The general feeling is that 440A (and similar steels, see below) is just good enough for everyday use, especially with a good heat treatment. 440-B is a very solid performer and 440-C is excellent.

425M - 12C27

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
0.54	0.35	0.00	13.5	0.00	1.00	0.00	0.00	0.00

Both are very similar to 440A. 425M (0.5% carbon) is used by Buck knives. 12C27 (.6% carbon) is a Scandinavian steel used often in Finish puukkos and Norwegian knives.

AUS-6 - AUS-8 - AUS-10 (aka 6A 8A 10A) (data for AUS-8 listed)

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt

0.80	1.00	1.00	18.00	0.00	0.75	0.00	0.00	0.00

These are Japanese stainless steels, roughly comparable to 440A (AUS-6, .65% carbon), 440B (AUS-8, .80% carbon) and 440C (AUS-10, 1.1% carbon). AUS-6 is used by Al Mar. Cold Steel's use of AUS-8 has made it pretty popular, as heat treated by CS it won't hold an edge like ATS-34, but is a bit softer and may be a bit tougher. AUS-10 has roughly the same carbon content as 440C but with slightly less chromium, so it should be a bit less rust resistant but perhaps a bit tougher than 440C. All three of the AUS steels have some vanadium added (which the 440 series lacks), which will improve wear resistance.

GIN-1 aka G-2

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
0.90	0.60	0.37	15.5	0.00	0.30	0.00	0.00	0.00

A steel with slightly less carbon, slightly more chromium, and much less moly than ATS-34, it is used often by Spyderco. A very good stainless steel.

ATS-34 - 154-CM

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
1.03	0.25	0.25	14.00	0.00	4.00	0.00	0.00	0.00

The hottest high end stainless right now. 154-CM is the original American version, but for a long time was not manufactured to the high quality standards knife makers expect, and so is not used often anymore. 154-CM may again be available. ATS-34 is a Hitachi product that is very, very similar to 154-CM, and is the premier high quality stainless. Normally hardened to around 60 Rc, it holds an edge very well and is tough enough even at that high hardness. Not quite as rust resistant as the 400 series above. Many custom makers use ATS-34, and Spyderco (in their high end knives) and Benchmade are among the production companies that use it.

ATS-55

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
1.00	0.50	0.40	14.00	0.00	0.60	0.00	0.00	0.00

Similar to ATS-34, but with the most of the moly removed and some other elements added. Not much is known about this steel yet, but it looks like the intent was to get ATS-34 edge holding with increased toughness. Since moly is an expensive element useful for high speed steels, and knife blades do not need to be high speed, removing the moly hopefully drastically decreases the price of the steel while at least retaining ATS-34's performance. Spyderco is using this steel.

BG-42

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt

1.15	0.50	0.30	14.50	0.00	4.00	1.20	0.00	0.00

Bob Loveless announced recently that he's switching from ATS-34 to this steel. Keep an eye out for it, it's bound to catch on. BG-42 is somewhat similar to ATS-34, with two major differences: It has twice as much manganese as ATS-34, and has 1.2% vanadium (ATS-34 has no vanadium), so look for even better edge holding than ATS-34. Chris Reeves has switched from ATS-34 to BG-42 in his Sebenzas.

CPM T440V - CPM T420V (data for CPM440V listed)

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
2.20	0.50	0.50	17.50	0.00	0.50	5.75	0.00	0.00

Two steels that hold an edge superbly (better than ATS-34), but it's difficult to get the edge there in the first place. These steels are both
high in vanadium. Spyderco offers at least one model in CPM T440V. Custom maker Sean McWilliams is a big fan of 440V, which he forges. Depending on heat treatment, expect to have to work a bit harder to sharpen these steels -- also, don't expect ATS-34 type toughness. 420V is CPM's follow-on to 440V, and with less chromium and almost double the vanadium, is more wear resistant and may be tougher than 440V.

400 Series Stainless
Before Cold Steel switched to AUS-8, many of their stainless products were marketed as being of "400 Series Stainless". Other knife companies are beginning to use the same term. What exactly *is* 400 Series Stainless? It might be 440-A, but there's nothing to keep a company from using any 4xx steel, like 420 or 425M, and calling it 400 Series Stainless.

NON-STEELS USED BY KNIFEMAKERS

Cobalt - Stellite 6K

Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Vanadium	Tungsten	Cobalt
1.20	0.80	0.00	28.00	0.00	0.00	0.00	5.00	60.00

A flexible material with very good wear resistance, it is practically corrosion resistant. Stellite 6K, sometimes seen in knives, is a cobalt alloy. David Boye uses cobalt for his dive knives.

Titanium
Newer titanium alloys can be hardened near 50 Rc, and at that hardness seem to take something approaching a useful edge. It is extremely rust resistant, and is non-magnetic. Popular as expensive dive knives these days, because the SEALs use it as their knife when working around magnetically detonated mines. Mission knives uses titanium. Tygrys makes a knife with a steel edge sandwiched by titanium.

Ceramics
Numerous knives have been offered with ceramic blades. Usually, those blades are very

very brittle, and cannot be sharpened by the user;
however, they hold an edge well. Boker and Kyocera make knives from this type of ceramic. Kevin McClung recently came out with a ceramic composite knife blade that much tougher than the previous ceramics, tough enough to actually be useful as a knife blade for most jobs. It is also user-sharpenable, and holds an edge incredibly well.