KNIFE DEBURRING

Science behind the lasting razor edge

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BURRS

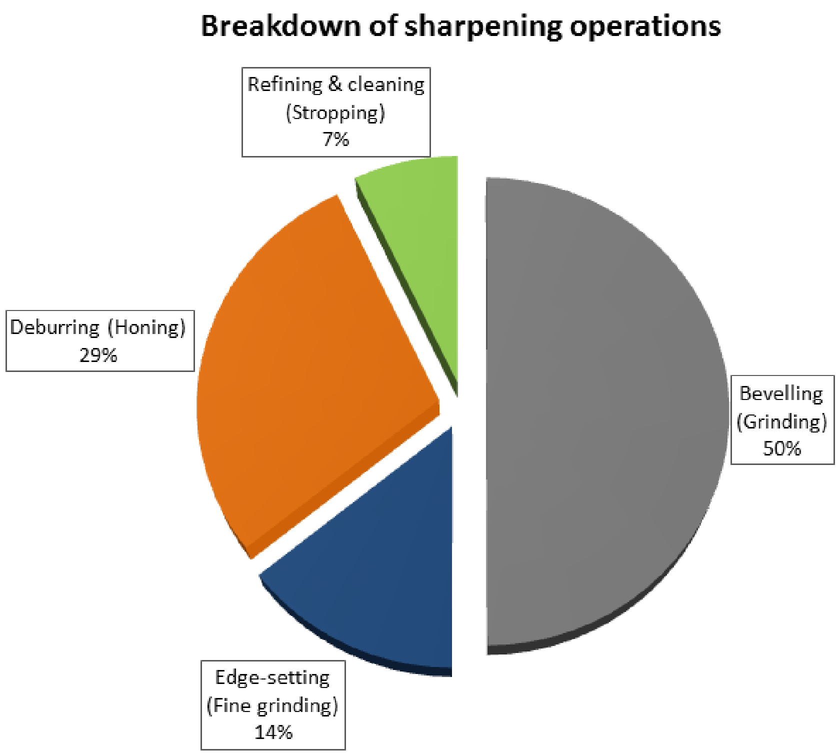
Erasmus Darwin, grandfather of Charles Darwin, was historically the first to mention the term "burr" in writing in 1784. By funny coincidence, I am writing this research in the same age of 53 he wrote about the burr. In the context of knife sharpening we can define ***burr*** as unwanted projection of **deformed metal** on the blade edge formed as a result from grinding or honing, undesired but to some extent unavoidable, while the knife edge apex is the metal next to the base of the burr.

The metal deformation at the edge during sharpening significantly influences the properties of this edge, weakening it - the higher the grinding speed and pressure on the blade, the weaker edge you get. Rough grinding can cause subsurface micro-cracking. An extreme of sharpening with a high RPM grinder or belt sander in sparks of liquefied steel is responsible for premature or catastrophic failure of the knife edge in the beginning of cutting.

Well-known two steps in sharpening a knife are edge-setting, also called “apexing”, and deburring, and deburring is more important since it determines how sharp and stable your edge will be.

We've been preaching proper sharpening methods and burr removal as the key to sharp edges for some time now and if you happen to be a sharpener who is having trouble achieving really sharp edges this research might just be the answer. It is not only about producing sharp edges though, it is about producing long lasting edges.

Newbie sharpeners often consider deburring as an unimportant non-value-adding operation. In reality, edge sharpness and longevity depend on proper deburring, and compared to bevelling and edge-setting (apexing), the deburring is more challenging because the edge is worked in the area only a few microns in height and submicron in thickness. Deburring is often a time-consuming and tedious task.



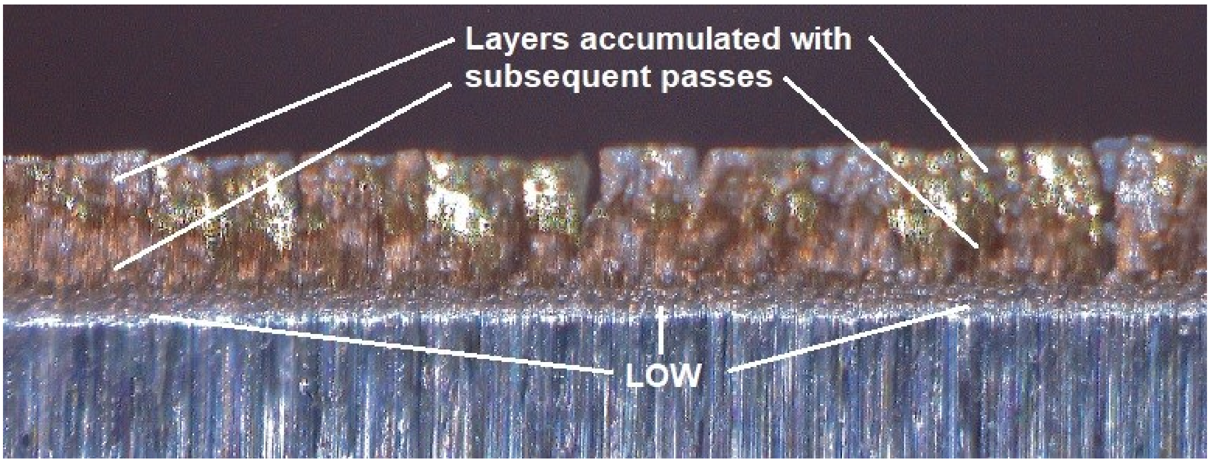
By timing in our workshop

Microcosm of sharp edges is fascinating. Edge apexes assume new mechanical attributes that are different from the metal they emanate from. Hardness ratings of the knife blade material do not translate to the edge apex strength in a direct fashion. Hardness is definitely a contributing factor in apex stability but not as directly translatable as some may think. From a logical standpoint this seems like straightforward reasoning – the edge apex will be different from the rest of the blade simply because the burr formation is the result of plastic deformation, and mechanical characteristics of metals that have been plastically deformed are changed – why would one expect the steel properties at the base of the burr stay the same as in the blade?

The edge apex is different from the rest of the blade in that it tends to roll similarly easy disregard of the steel hardness and wear-resistant properties. When comparing resistance to rolling in the first cuts, we see that high-end knives lose the initial keenness of the 0.05-0.2 micron apex at near the same rate as mainstream knives; the edge apex width must be over 0.2 micron to see difference in the steel cutting performance. This fascinating paradox is explained in the chapter on high-end knives.

No one needs a burr, but it certainly helps to ensure you've got the apex all along the edge. When I hear of burrless sharpening I feel like people telling me of a pink unicorn. You will always have a burr off an abrasive when the apex is reached, whether you know it or not – where it is not visible, it can be felt by tactile receptors in your fingers, and where can not, it can be seen in the microscope. What we have learned is that burr formation begins long before any of us can actually detect it tactilely.

There is one very special zone at the base of the burr, right between the burr and the edge apex, designated as LOW on the below optical microscope image showing layers of the burr.



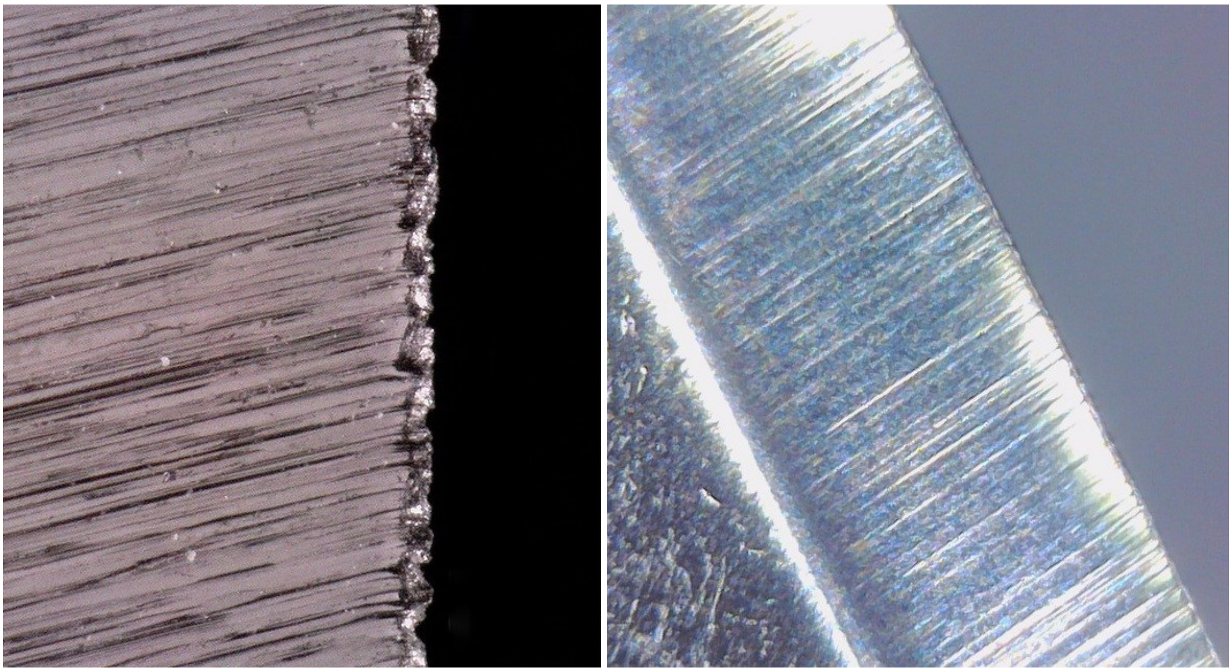
By courtesy of the BESS Forum bessex.com

In fundamental burr studies it is designated as the "burr root"; sometimes it is also called "secondary burr" in the specialist literature as the burr remaining after breakout of the bulk of the primary burr.

The ***burr root*** is different from the body of the burr in that it is formed by the first layers of the redepositioned metal solidified on the sharpened edge. We know that the burr root next to the apex is more difficult to remove than the outer layers of the burr. The burr root is adjacent to the micro-fractured weakened metal in the edge apex deformed by sharpening. The micro-hardness in the burr root is higher than in the base metal. [1]

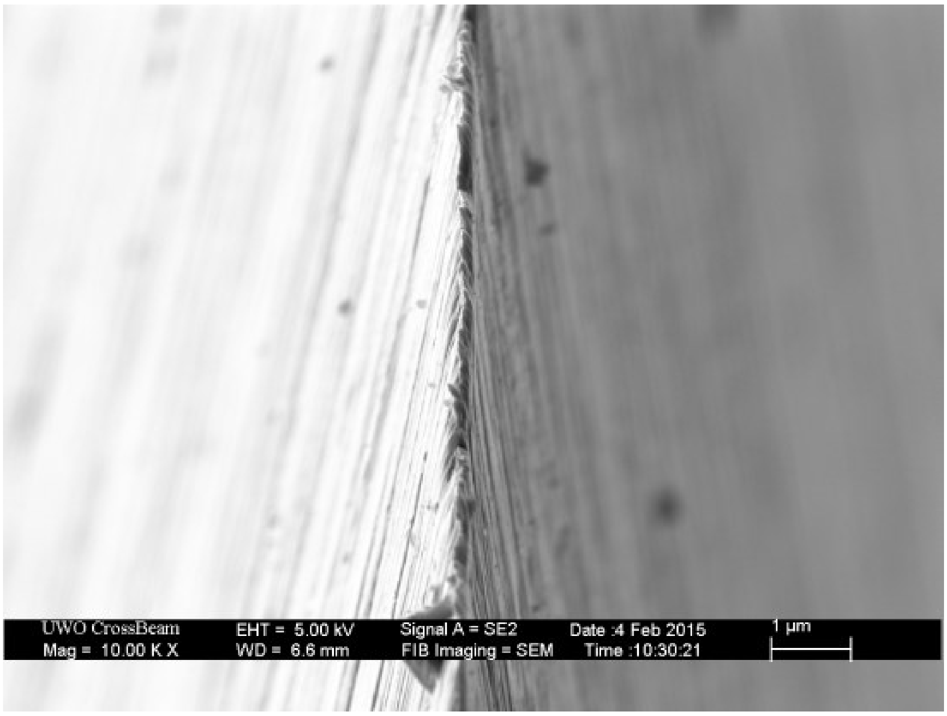
The enhanced micro-hardness of the burr root allows shaping it into an extremely sharp brittle edge called “wire edge”, sitting on a relatively weaker base. ***Wire edge*** is defined as a product of burr honing, when the burr root is shaped into an edge rather than deburred.

The following optical microscope image shows a burr off a coarse abrasive that is easily felt by brushing a finger across the edge, and next to it a blade with the wire edge that you cannot see and cannot feel.



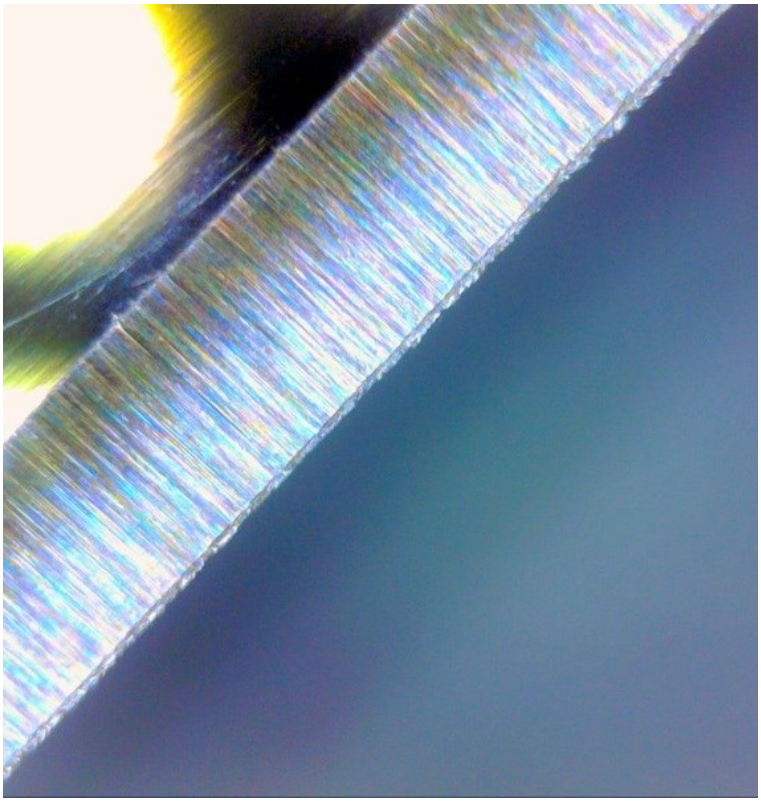
By courtesy of Tony Spielberg, USA

The wire edge by SEM (edge-on view):

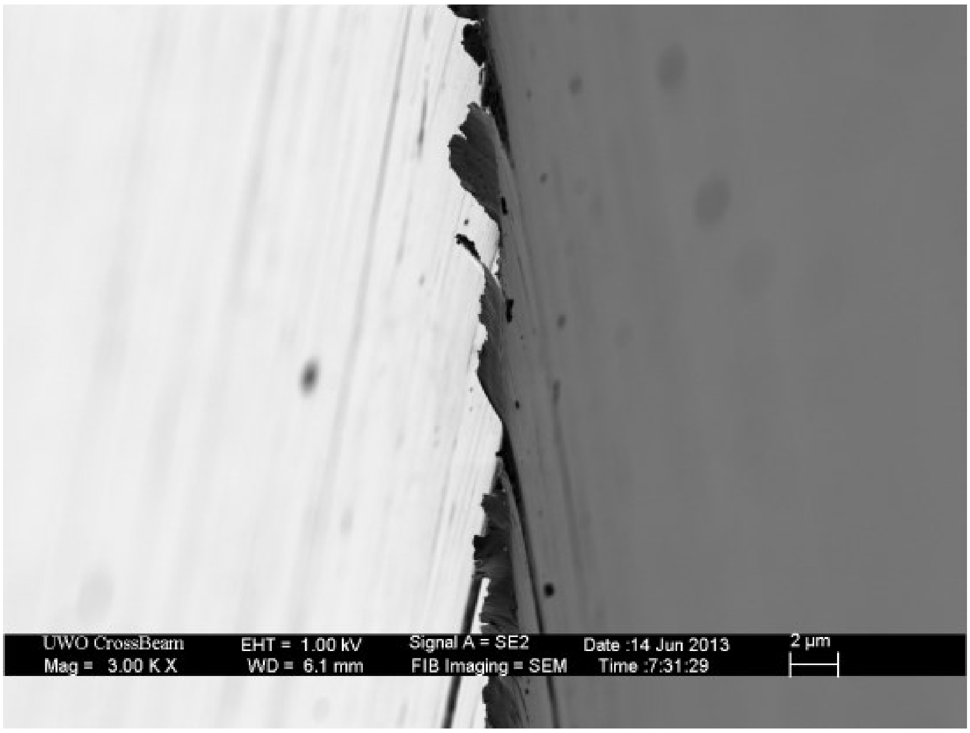


SEM images are by courtesy of Todd Simpson (scienceofsharp.wordpress.com)

“Feather burr” and “Foil edge” are two more edge geometries that can be created in the finishing stage of removing the burr – these two are near synonymic and are a product of edge-trailing honing at the edge angle - shown on the following optical and SEM microscope images.



Feather burr

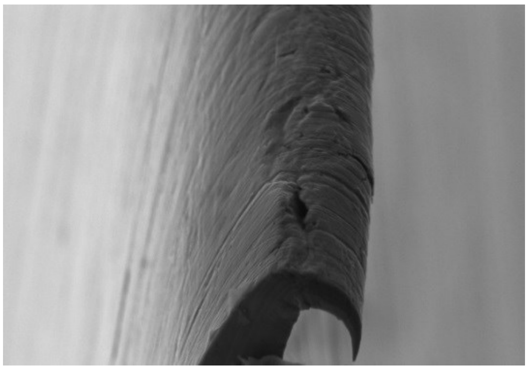


Foil edge

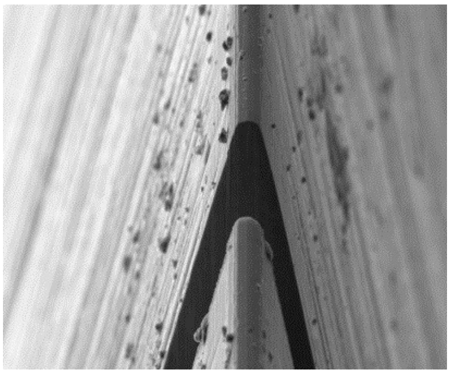
We can recognise presence of the wire or foil edge by the edge behaviour during cutting.
An obviously ultra-sharp edge that whittles hair will start a smooth cut but end with tearing, or show clean cuts alternating with ragged - indicating a weak edge folding in the process. If the edge is not cutting well, it can mean one of two things: either it has not been fully apexed, or there is a burr or crushed wire/foil edge getting in the way.

The wire edge crushes under a minimal load by mushrooming seen on SEM microscopy.

Dulling of the normal edge goes differently: where the load is perpendicular to the edge, it may mushroom, and where at an angle it rolls over, but more typically we see ***abrasion wear*** in the used normal edge. The wire edge, being too weak to hold the load, won't ever show the abrasion wear typically seen in the used normal edge.

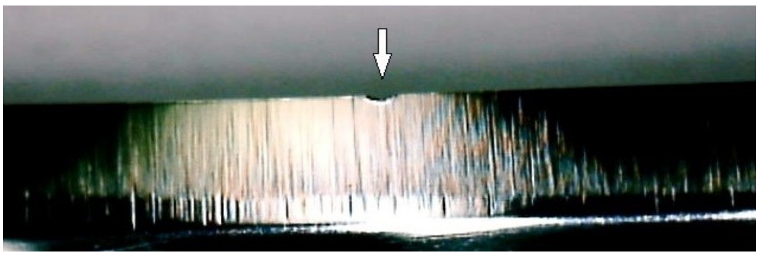


SEM – Normal edge rolling



SEM – Normal edge dulling through abrasion wear

What we see on the BESS sharpness tester?
Because the wire edge is too weak to cut the test line, it crushes on it and, as we increase the downward pressure, mushrooms against the test line allowing to apply more pressure onto the widening point till the line gets finally severed. In the point of testing, we see a micro-dent in the edge with the mushroomed apex displaced to the dent bottom, and the sharpness reading is a level of magnitude worse than we would expect by seeing the same edge cut hair and push-cut rolling paper.



A sharp knife that fails early usually is the result of a wire edge that hasn't been properly removed. A good sharpener knows how to apex and deburr the edge; an expert sharpener knows how to clean the apex of the weak wire edge not rounding it.

The wire edge is fairly common as too often the base of the burr is not removed completely. It is just so fine that it is not detected by the 'finger method' most people use. The end result is the wire edge that dulls extremely quickly once the wire gets mushroomed with the first cuts.

Let’s have a closer look into the two sharpening steps of apexing and deburring.
A correctly apexed edge shows a scratch pattern to the very apex on both sides, and a one-sided burr. When setting the edge, it is best to flip the burr to be sure you have a scratch pattern up to the end of the apex on both sides. The off-burr side should have a perfect scratch pattern all the way to the apex top - that's what makes the burr on the burr side.

As you start deburring the burr side, it may feel like the burr is flipped, but what feels like a flipped burr is only the flimsy end of the burr. When normal deburring methods are employed, more often than not, the top layers of the burr are removed but leave the base of the burr intact and still stuck to the edge in the form of the wire edge. The wire edge, by its genesis, seems to be the very first layer of the burr laid down and is really well stuck to the edge apex. We think this layer at the base does not flip with the rest of the burr in the process of deburring.

How do we clean the edge apex of the root burr and wire edge?

It is a bad practice (though common) to draw the edge through a wood block, rubber or cork to “rip off” the remnants of the burr. If you do, the metal crud will build up on the front of the slice, and you'll be dragging the rest of the edge through the crud and this, together with breaking off of ledges of material along the edge, will roughen the edge and worsen sharpness.

The following SEM images by courtesy of Todd Simpson show the burr on his ZDP-159 knife in the left image, that was then “ripped off” by cutting cross-grain into a piece of redwood in the right image – loss of the sharp edge is obvious.

If you strop the wire edge on a clean leather strop or belt, smooth side or rough side, it usually won't come off. Leather is too soft to affect steel in any meaningful way. You need something harder than steel to remove the wire edge, and that's what honing compounds are for. However, the honing compound is only part of the solution, because the wire edge has such a low profile that honing is unable to pick it up so that it can be removed; subsequent passes just seem to add volume to it, turning it into a foil edge. Basically, you are polishing the burr rather than cleaning the apex.

To deburr cleanly, i.e. to clean away the burr root and the weakened steel, we select one of several methods, depending on the blade steel. The blade steel predetermines how the burr forms, and the way the burr forms determines the most appropriate deburring method. Correct deburring method produces edges with greater longevity.

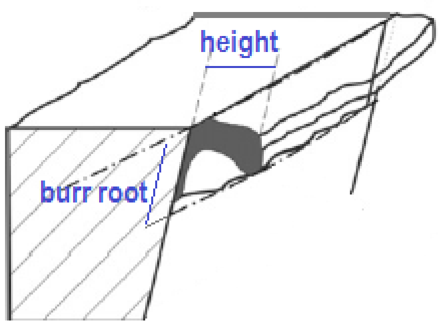
Burr formation is understood to a good extent, and our research has concentrated more on the application of the theoretical understanding in order to improve the cutting edge quality. We had to learn how to recognize the wire edge, how to remove, and finally how to prevent it. The occurrence of wire edge in edge-trailing honing is more common than commonly thought as we cannot see and palpate it, it is near impossible to detect without instruments, and it is usually revealed only by premature edge dulling in routine cutting.

BURR MINIMIZATION

We have to put up with the fact that burrs can not be avoided, only minimized - burr control rather than burr avoidance is a realistic practical approach.

The mechanism of burr formation during sharpening is an extremely complex phenomenon. Many factors affect the burr size and behaviour, the most significant being properties of the steel and the abrasive, edge-leading versus edge-trailing grinding, the grinding angle, grinding speed and depth.

The appearance of the burr is influenced by many factors, and due to the diversity of forms the burr shape classification is impractical. But there are two parameters that matter - the burr height and the burr root thickness.



A comparison between conventional (aluminium oxide or silicon carbide) and superabrasive (CBN cubic boron nitride or diamond) grinding wheels reveals that for conventional wheel burrs tend to be of a long and thin shape whereas for superabrasive wheel the burrs tend to be relatively small and thick.

Decreasing the grinding angle leads to increasing burr size and widening its root; increasing edge angle leads to a smaller plastic deformation zone and smaller burr. As you can easily imagine by this rule, an edge sharpened at 20 degrees will require more deburring efforts than the edge sharpened at 40 degrees.

In edge-leading grinding burr formation is lower because the material is restricted to deform in the direction of the grinding force. We learn from general machining, as soon as we've drilled or sawed the ever first workpiece, about the difference between the entrance and exit burr; the exit burr is also known as a "rollover burr". The tiny entrance burr can be likened to edge-leading sharpening (into the stone/wheel), and the prominent exit burr to edge-trailing (away from the stone/wheel).

Edge-leading sharpening produces a smaller burr and is preferred on the coarse, medium and fine grits to as fine as JIS 8000; honing on finer grits however is better done edge-trailing.

Positive effect on burr minimization has edge-leading grinding, low grinding wheel/belt speed but higher blade feed rate, use of aggressive cutting abrasives (CBN/diamond or refreshed grains in conventional abrasives e.g. a freshly trued stone wheel), wet grinding and use of metalworking fluid/coolant.
It is not simple to adjust sharpening process for burr minimization due to constraints like the available abrasives, target edge angle, required surface finish, and time allowance per knife.

POSITIVE AND NEGATIVE BURRS

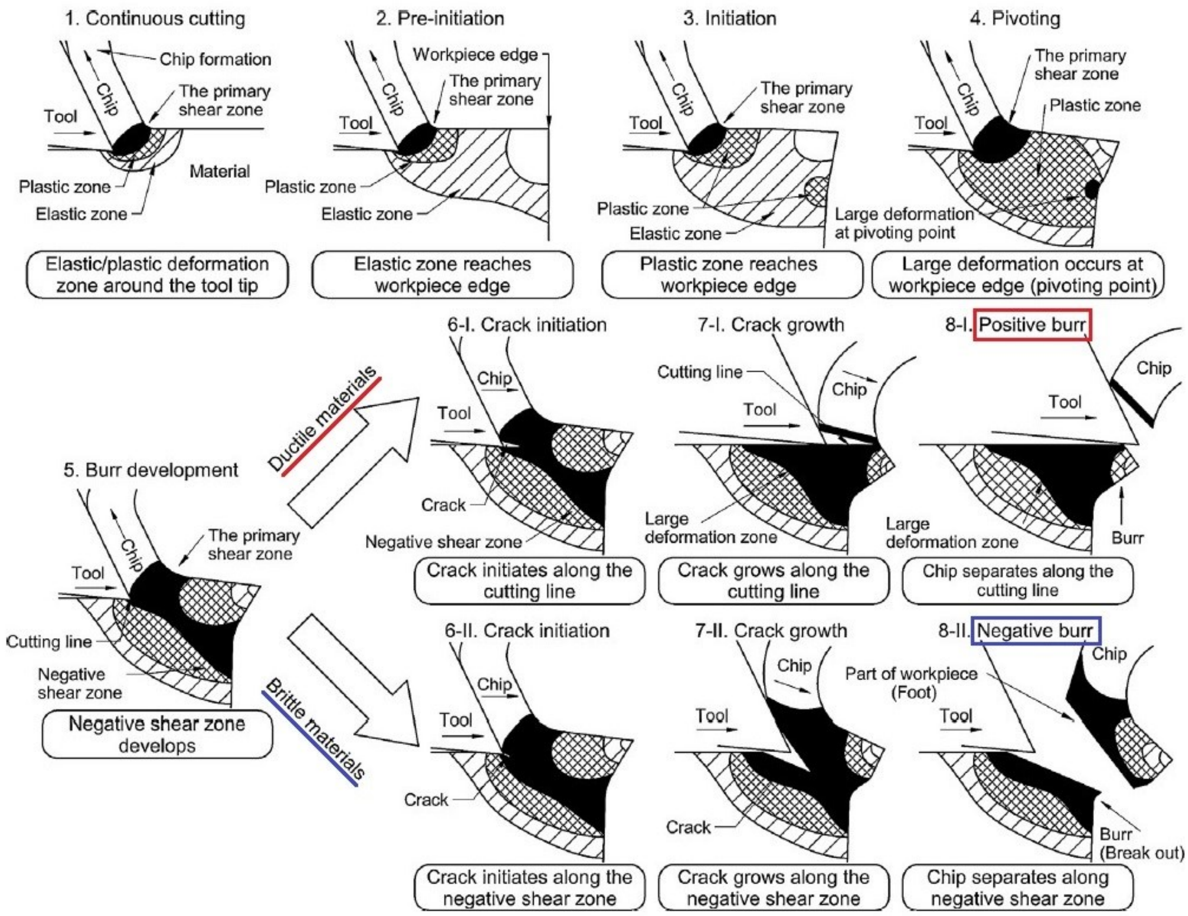
Selection of the deburring method significantly depends on the burr malleability. The burr malleability, in its turn, depends on the properties of the steel and (to a lesser degree) on the abrasive, and these predetermine whether the burr will be forming by positive or negative mechanism.

Positive burrs are produced in tough ductile steels, while negative in hard and brittle.
Positive burrs form by shifting the deformed steel to the side of the apex, while the negative burrs form by shearing and chipping the deformed steel.
Positive burrs are a plus-material stuck to the edge apex, malleable and difficult to break off, while negative burrs are brittle and chip off rather than bend.
Positive burrs are deburred by honing at a higher than the edge angle, while negative burrs can be deburred by honing at the edge angle.

I oversimplify purposely to make the complex phenomenon of burr and deburring somewhat easier to comprehend. Oversimplifying and generalizing to the utmost, we can contrapose the two types of burr as the following:

MALLEABLE POSITIVE BURR	BRITTLE NEGATIVE BURR
A high foil-like burr on a thin root. A burr created edge-trailing, with conventional aluminium oxide and silicon carbide abrasives, and the majority of natural stones, using excessive pressure or high grinding speed.	A small stiff burr on a wide root. A burr created edge-leading, with CBN/diamond abrasives, using minimal pressure and low grinding speed.

The following schematic of the positive and negative burr formation is probably the most comprehensive, and if only a human mind could grasp the information without the need to first analyse it, we could finish our discussion by simply viewing this diagram.



Burr formation scheme for materials: brittle and ductile [2]

What is marked as "elastic zone" on the diagram, in actual practice appears as a recoverable bending of the edge, while "plastic" is the permanent deformation that turns into a burr in step 4. As the crack propagates and the shear zone extends, the burr grows increasing in size.

The first five steps of the burr formation are similar to all types of steel, and show the behaviour to crack initiation; the last three steps illustrate the differences in the direction of crack propagation along the shear zone between the "ductile" and "brittle" steels. In the case of "ductile steels" the crack propagation occurs in the direction of grinding, and the ground material forms the "positive" burr. In case of "brittle steels", the crack fractures at an angle to the direction of grinding, in the direction to the line of resilience to deformation and as a result the ground material separates from the workpiece and the burr tip chips off. The "negative shear zone" that develops in step 5 is a secondary shear zone below the plane of grinding, towards which the negative burr break out propagates.

Keeping in mind that cross-hatched in the illustration is the zone of plastic deformation or, simply put, the weakened steel, take a closer look at the negative burr final step, and note that even when no burr is overhanging, we still have to hone away the deformed metal and micro-fractured surface (cross-hatched) till the clean non-stressed edge.

SELECTION OF A DEBURRING METHOD

Having gained a basic understanding of the mechanisms underlying burr formation we can turn our focus to deburring.

Data relevant for knife deburring include the blade steel, type of the burr, grinding method applied prior to deburring, edge roughness, and the objectives of deburring since the consumer expectations about the edge quality differ widely. Main factors influencing knife deburring complexity are the burr type, and the shape and length of edges to be deburred; e.g. recurve S-shaped edges are more difficult to deburr. A crucial factor in selecting the deburring process is knowledge of how the deburring process itself affects the edge finish and residual stress.

There is a number of deburring procedures used in knife sharpening, and I will detail our technique for deburring different types of burrs after we discuss how to recognize those types.

Why recognising the different types of burr is so important? - because honing the positive burr at the edge angle shapes it into a wire edge that wouldn't last, while honing the negative burr at an angle higher than the edge rounds the edge causing an avoidable loss of keenness.

In the context of knife sharpening, the term “negative burr” is an umbrella term, not fully matching the connotations given to it in the metallurgical science. It goes without saying that positive and negative burrs in clear form are less common than combinations in-between, yet classifying knife steels by this polarized construct has proven useful in selecting the appropriate deburring method.

Steel properties is the most important factor in predicting whether the burr forming will go along the positive or negative path: hardness, ductility, tensile strength, yield point and fracture strain contributing the most.

KNIFE STEELS PRONE TO POSITIBE BURR	**KNIFE STEELS PRONE TO NEGATIVE BURR**
Tough, ductile, low hardness, low carbon and fine carbide steels. Examples: Mainstream stainless steels 1055, 1060, 1085, 1095 420, 420J2 440A AUS-6 5160 Z60CDV14 (Z60) AEB-L Elmax CPM 1V CPM 3V Sandvik 12C27 CPM S35VN …	Brittle, high hardness, high carbon and large carbide steels. Examples: 440C CTS-XHP 52100 D2 K110 CPM M4 CPM 4V M390 and CPM 20CV Vanadis-4 and Vanadis-10 Vancron 40 CPM S90V and CPM S110V ZDP-189 Aogami Blue-1 …

Examples of the broadest group of steels in-between: CPM-154 and ATS-34, AUS-8 and AUS-10, 8Cr13MoV, Sandvik 14C28N, S30V, VG10, N690 etc.

DEBURRING

We've learned so much about burr thanks to the sharpness tester and it is a formidable foe. Removing the entire burr while preserving the edge apex does not seem to be a simple, one size fits all, process. Unfortunately, no single deburring operation can accomplish all required edge conditions on every edge for every burr without side effects. In the deburring process that we use the burrs are removed by mechanical abrasion using controlled-angle supports for knife jigs. Deburring on a slotted "washboard" paper or rock-hard felt wheel includes a beneficial vibratory component and has an added edge-strengthening effect through work-hardening.

We employ several methods to successfully clean the knife edge of the micro-burr:

1) For steels prone to negative burr - by honing edge-trailing at the edge angle.

Note that this method will not deburr steels in which toughness and ductility prevail over hardness, including mainstream stainless knives. It is plainly impossible to deburr a blade with a malleable burr by honing it edge-trailing at the edge angle - you can only burnish the micro-fractured metal in the burr root into a wire edge.
However, we get many quality steels from the “in-between group” sharper than razors by this method – technicalities follow on the next page.

2) For any steel - by a higher-angle edge-trailing honing.

- For high-end and tool steels it is by 0.4 - 1 degree higher than the edge angle;
- For mainstream steels it is by 1.2 - 1.6 degree higher than the edge angle;
- For lower-end steels it is by 2 degrees higher than the edge angle.

As you “sink” the apex into the compressible material, and you can do this on leather, balsa, felt or a paper wheel just as easily as on a hanging denim strop loaded with a fine honing compound – the abrasive crystals will cut at the base of the burr.

This is a time and cost-effective method of choice for steels with a positive burr.
Note that by higher-angle honing of steels prone to negative burr, you get them deburred at the expense of losing some sharpness due to the apex rounding.

3) Edge-leading deburring works for any steel.

There are convincing SEM images supporting the concept that the apex micro-chipping characteristic of edge-leading sharpening limits the useful abrasive grits to JIS #8000. If one continues edge-leading on grits finer than that, the micro-chipping will be negating further apex refinement.

There are two constraints with edge-leading deburring: the honing angle control and the available finest abrasive. The devices providing for controlled-angle honing come with a limited selection of abrasive grits, e.g. the Tormek finest wheel is # 4000; while freehand honing on finer bench stones vary the strokes angle by +/- 3 degrees, risking abrading off the edge apex in the process.

A shortfall of this method is that you are introducing a new microscopic burr.

Edge-leading deburring is usually followed by edge-trailing stropping; high-angle stropping is recommended for softer steels. However, in common knife applications edge-leading sharpening is considered satisfactory even without stropping, since the controlled burr is acceptable due to its small size. There are also contrary speculations that grinding into the wheel stresses metal more than away from the wheel, and this stressed metal must be removed by edge-trailing fine honing or stropping in the finishing step.

Whenever you decide to finish your edge-leading sharpening with edge-trailing passes, you have to follow the rules outlined above.

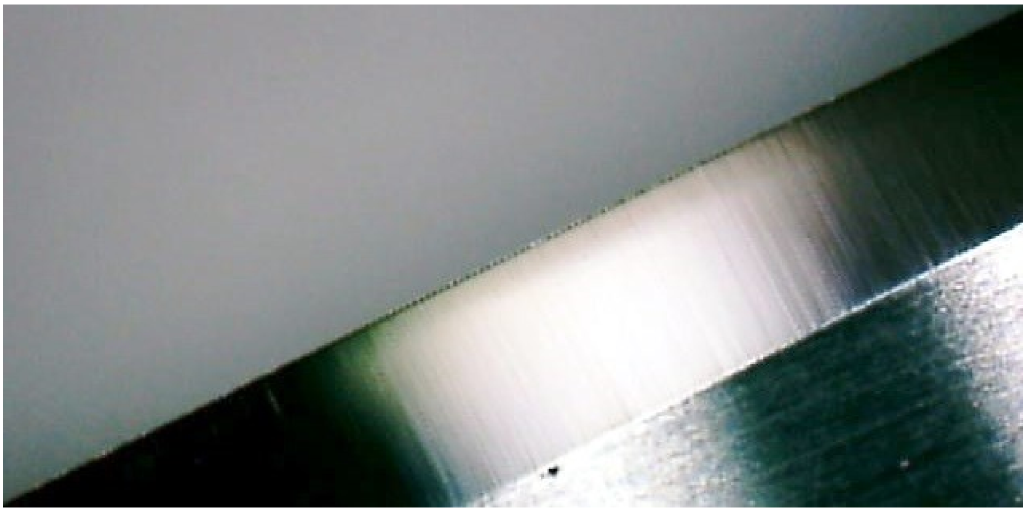
Before we can hone away the burr root and the adjacent stressed metal by any of these honing modes, we have to thin away the bulk of the burr to expose the "burr root". That's why we say that proper deburring requires a minimum of 2 steps.
Let me detail how we do each mode.

Honing at the edge angle

We set 2 honing paper or rock-hard felt wheels - one at a shallower than the edge angle, by 0.1 - 0.3 degree less, e.g. a 15 degrees per side (dps) edge will be honed at 14.7 - 14.9 dps, and the second wheel at the exact edge angle.

The first shallow honing wheel is thinning away the bulk of the burr, and has a 3-6 micron honing substrate. The 2nd wheel is honing away the root burr to the clean apex, and has 0.25 - 0.5 micron honing substrate.

After honing on the first wheel at a slightly less than the edge angle, the edge looks like on the following microscope image:



That fringe of unpolished apex that you see at the end of the polished edge is sharp as a razor, and averages 0.1 micron in width - we take this edge from razor sharp to sharper than a razor by honing on the second paper wheel impregnated with 0.25/0.5 micron diamonds at the exact edge angle.

In the process of honing I may move the blade between these 2 wheels several times, each time checking sharpness on the tester.

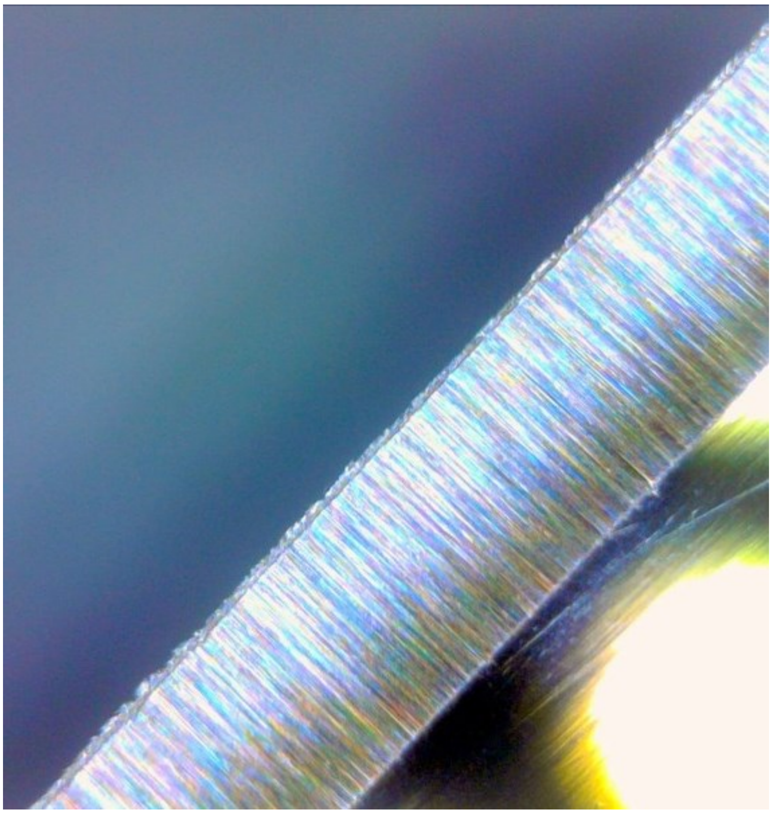
I use this honing mode on blades of hard steels prone to negative burr when asked to sharpen a knife to the "bragging rights" utmost sharpness. Typical sharpness score is 25-50 BESS, sometimes 15-20 BESS - i.e. that of a production razor or sharper, **under 0.1 micron edge apex**.

On quality steels, I may use edge-trailing honing on a Japanese wheel #4000 to get a knife sharper than razors. This method is described in detail in the case study in the full edition of the book.

<u>Honing at a higher angle</u>

We set 2 honing paper or felt wheels - one at the exact edge angle*, it will hone away the bulk of the burr with a 3-6 micron honing substrate; and the second at 0.4 - 2 degree higher angle depending on the steel as specified above (e.g. a 15 dps edge will be honed at 15.4 - 17 dps), it will hone away the burr root and has 1-micron honing substrate. It took us a lot of sharpness tests in trial and error to conclude that the **1-micron abrasive de-roots the burr best of all**.

After honing on the first wheel at the exact edge angle, the edge ends with a wire edge or feather burr like on the following microscope image:



We remove the burr root on the second rock-hard felt wheel with 1-micron diamonds at a higher angle. (In our workshop we call this step “de-rooting”.)

I use this honing mode for the majority of practical edges. Typical sharpness score is 55-90 BESS - i.e. nearing the production razor, **0.1 - 0.2 micron edge apex**.

* When a knife steel is really low in hardness and carbon, e.g. HRC 53-55 and carbon <= 0.45 - I will set the first wheel at +0.4 degree higher, rather than at the exact edge angle, i.e. a 15 dps edge will be honed at 15.4 dps on the first 6-micron honing wheel, and at 17 dps on the second 1-micron wheel.

Edge-leading mode

In edge-leading sharpening we maintain the exact edge angle through all grits progression.
On Tormek Japanese wheel JIS #4000 knives get sharpness averaging 150 BESS, and after stropping with chromium oxide come under 100 BESS. The sharpness tester reading of 150 BESS tells us of **0.3 micron apex width**, and this is consistent with the scanning electron microscopy of an edge set edge-leading on #4000 showing 0.3 micron apex. [3]

Time-wise edge-leading deburring takes longer than honing at a higher angle on paper/felt wheels, and is less forgiving to mistakes in the honing angle.

Cleanup

The finishing cleanup includes gentle swipes on bare leather, typically on a hanging strop;
or stropping on a denim, balsa or nano-cloth strop, or a paper wheel with <= 0.5 micron honing agent.

In our workshop most often it is done by a single pass on a paper wheel with a mix of Chromox (which has 0.3-0.5 micron particles) and 0.25 micron diamonds at the exact edge angle. To get a keen edge capable of whittling hair, finishing must be done with <= 0.5 micron abrasive particles, and minding that manufacturers rate their honing compounds by average particle size, to be sure you get particles under 0.5 micron we use those labelled as 0.25 micron, understanding that they will still have a fraction of particles 0.5 micron in size. If you'd use 0.5-miron labelled compound you would have a fraction of particles near 1 micron, not good for finishing the apex.

Finishing is important to clean up the deburred areas on the edge from any weak metal left after the burr breakout to get an "ideal" apex. Got to be very careful here, as even the bare leather may destroy the maximal sharpness of your edge at its apex – the passes on a strop are as gentle as would be shaving the face, only edge-trailing.

Some of sharpeners finish with steeling on a smooth polished steel, using extremely light pressure under visual control of the edge contact with the steel surface.

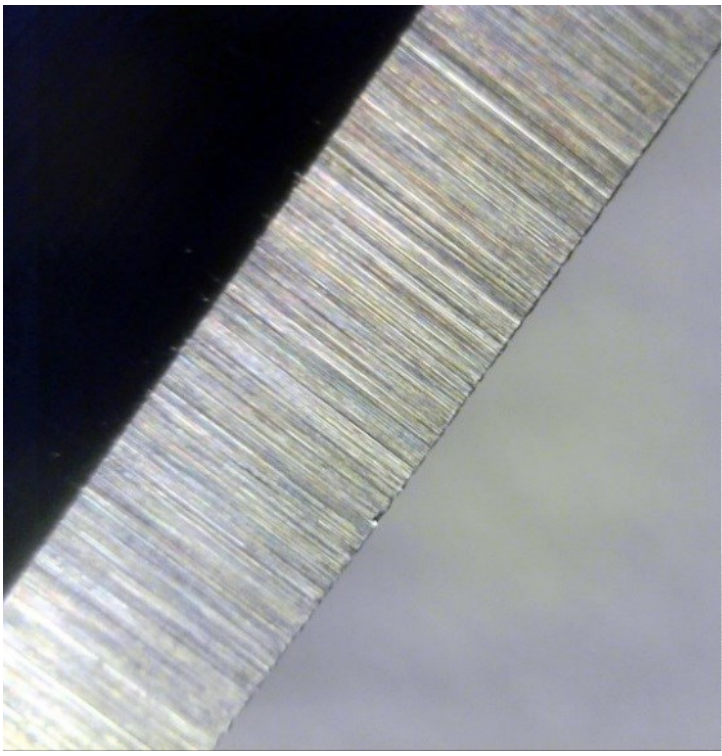
Note that the substrate the honing abrasive is on is as important as the abrasive itself.
Leather, balsa, felt, paper wheel and linen or cotton used in deburring are not equal - not every burr can be "de-rooted" on all of these substrates.

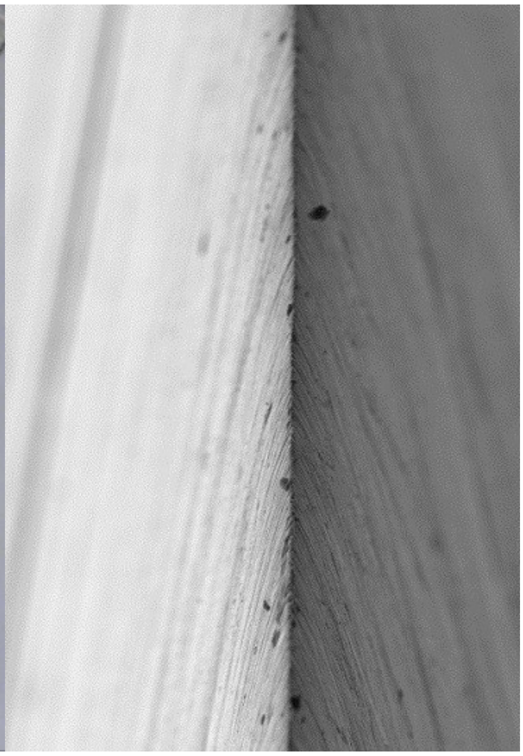
By aggressiveness we group them in 3 groups:
denim/linen/cotton, paper wheels and balsa;
next comes the leather;
then suede;
and the most aggressive is felt which works well for both super-steels and those deburring headache stainless steels at the low end.

The less aggressive is the honing substrate, the longer takes honing to attain the same degree of edge cleanliness; however less aggressive substrates are preferred for finishing.

Only once you eliminate the burr root, you get a strong, lasting edge. A correctly deburred edge shows nothing except the clean scratch pattern going to the end of the apex.

Optical and SEM microscope images of a cleaned edge follow.





A perfectly deburred edge is extremely robust to the work load.
The photo shows Mike Brubacher’s experiment with perpendicular load on the shaving sharp edge with a flat end of a hardened steel rod: 2140 grams (about 4.7 lbs) load on a hardened 5/16" steel rod did not effect the burr-free edge of a mid-range Henkel chef's knife - the same BESS reading of 160 BESS and unchanged optical microscopy – 160 BESS means shaving sharpness.

By courtesy of the BESS Forum bessex.com

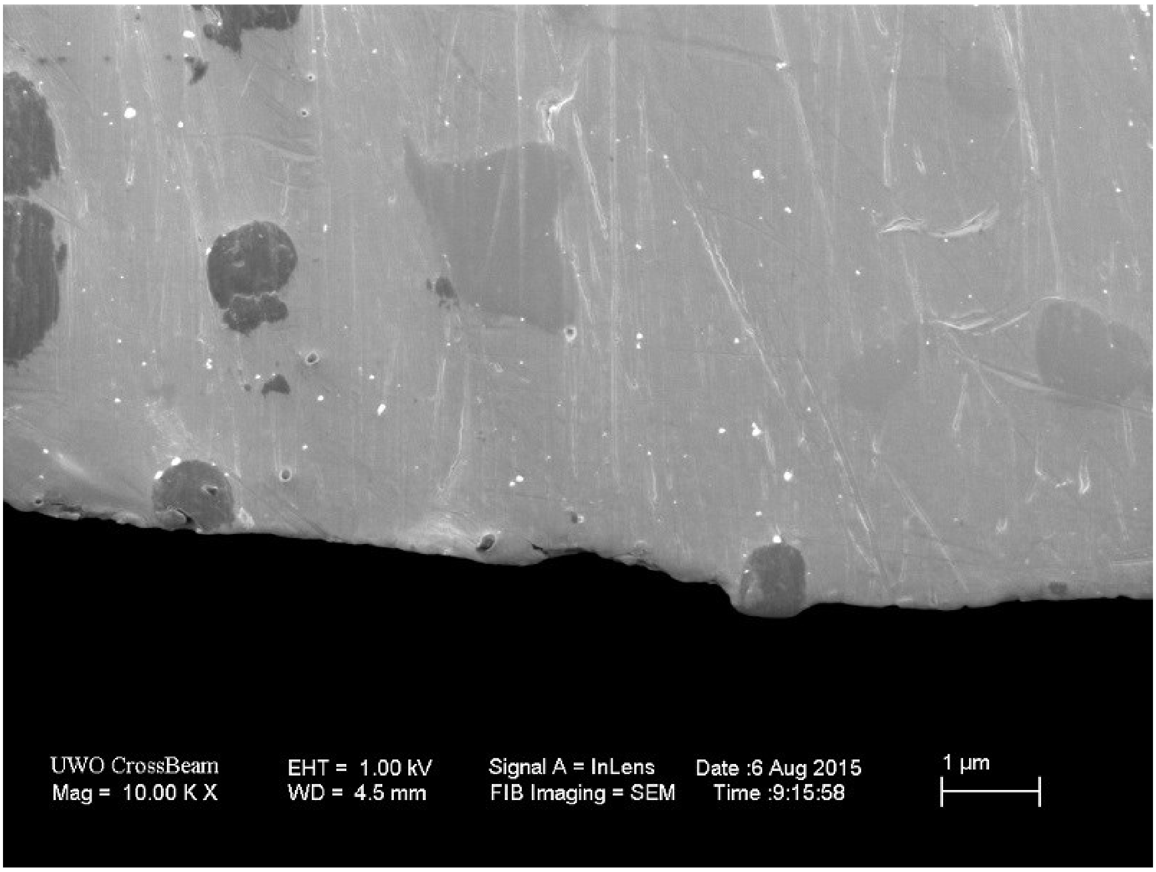
HIGH-END VERSUS MAINSTREAM KNIVES

Facts debunk the myth that super-steels hold super-sharp edge. Facts tell us that the initial blunting rate is relatively rapid regardless of steel. Though high-end wear-resistant edges win in the long run, they lose their initial keenness almost at the same rate as a mainstream knife. High-end knives win over mainstream as stayers, but they are equal sprinters. High-end knives and mainstream knives lose the initial keenness of the 0.05-0.2 micron apex similarly easy, but past this point the similarity ends.

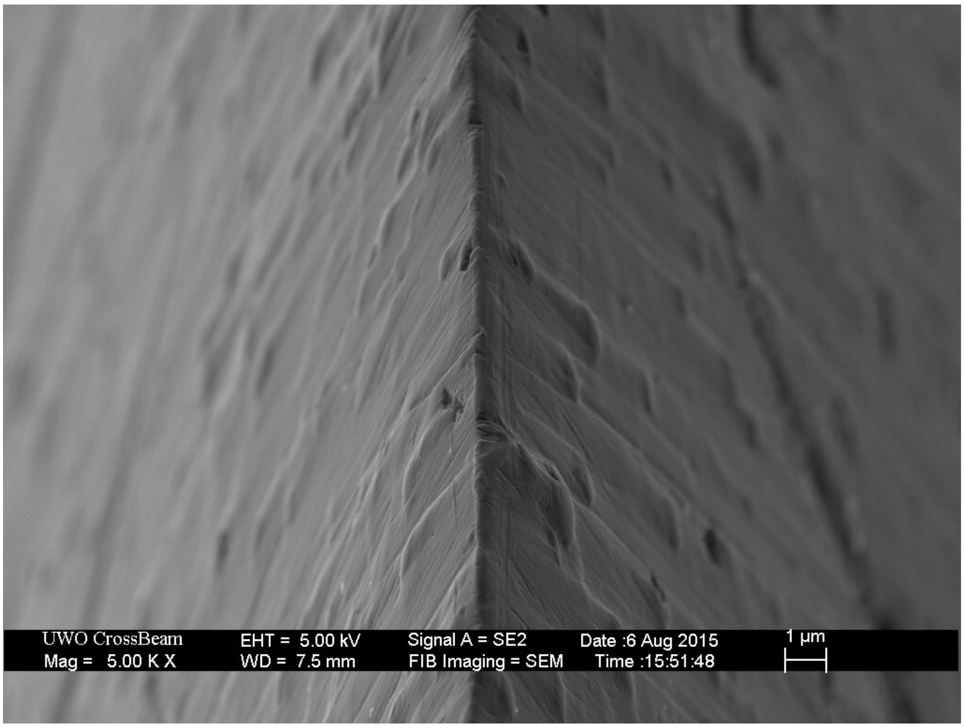
We've seen this in our BESS-SET (**S**tructural **E**dge **T**ester) tests on edge stability, in CATRA tests done by Larrin Thomas (*knifesteelnerds.com*), in Nathan Stuart's tests on edge retention in high-end knives (presented on our website), and everyone who sharpens his high-end knives knows this at first hand.

There is a simple explanation to this phenomenon. What makes a knife steel high-end is the large volume of wear-resistant carbides, and these carbides are 10s times the size of the razor edge. For example, vanadium carbides sitting in the steel matrix average 20 microns in size in conventional tool steels (e.g. D2 steel), and 1 to 5 microns in CPM steels, while the razor apex width is under 0.1 micron. The question is if we really can polish those wear-resistant carbides as fine as to the 0.1 micron razor edge when we sharpen them with diamonds and CBN?

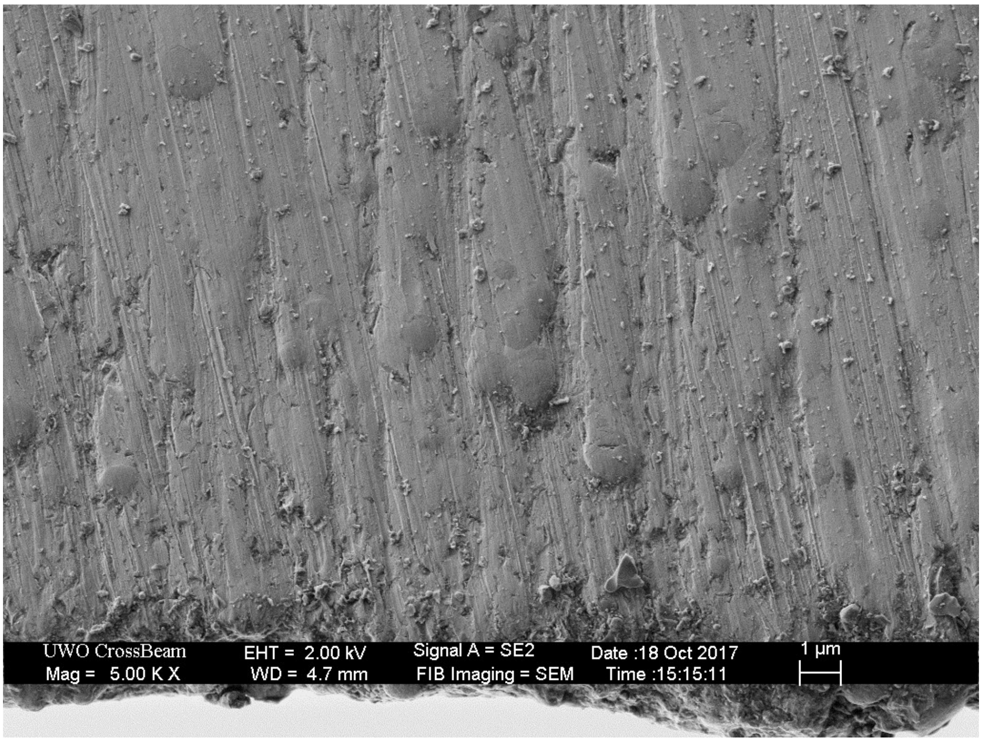
Todd Simpson's SEM image of a CPM S30V shows spheroidal vanadium carbides near the edge:



Edge-on view of the same S30V knife sharpened with aluminium oxide abrasives – because the vanadium carbides are harder than the abrasive, they sit a bit proud of the matrix abraded off around them:



A SEM image of another S30V knife honed on Shapton #16000 – the surrounding matrix can be seen abraded around vanadium carbides, and the carbides become raised bumps on the surface of the bevel:



The above SEM images clearly show that when we sharpen a tool steel or high-end blade using anything but diamonds and CBN, it is not possible to polish those wear resistant carbides sharp, as we'll only be abrading the steel matrix around them, burnishing it to the edge, and eventually getting a very sharp steel edge that won't last long. As we start cutting with such an edge, the ultra-sharp steel apex quickly turns into a **relatively dull edge made of big unpolished carbides**.

Production DE razors have near 0.1 micron edge, a dull knife has over 1 micron edge, and the unpolished vanadium carbides average 1-2 microns in that SEM images of the CPM S30V knife edge. Yes, we can easily strop it back to razor sharp by burnishing the steel matrix over the edge and shaping it into a razor edge, but this edge will be short-lived without fine-polishing the vanadium carbides, which only diamonds and CBN can do.

I believe that even when we sharpen high-end knives with diamonds and CBN, the hair-splitting razor edge we get on them is the edge apex formed from the steel matrix burnished over the wear-resistant carbides, rather than the carbides themselves. This explains why the apex ultra-sharpness goes away equally quickly in the high-end and mainstream knives - because it is still the steel. That tiny strip of steel lacking in wear-resistant carbides at the very tip of the edge wears quickly until there are sufficient carbides to slow the wear of the edge. But the advantage is that past this point, typically past the edge apex width of 0.2 micron, the high-end knives honed with CBN and diamonds hold the sharp edge far better.

Sharpening a wear-resistant knife is very different to a regular carbon steel, and requires a sequence of progressively finer diamonds/CBN, it actually has more in common with sharpening ceramic knives than a carbon steel knife.

A regular carbon steel knife we apex and deburr, and can get a lasting sharp edge even off a grit #150-300 abrasive. A wear-resistant knife we apex, and then polish and polish through a sequence of progressively finer grits diamonds/CBN; there is no way you can get a lasting sharp edge even off the #1000 - you need a finer grit than that.

If you don’t have coarse diamond or CBN, no problem bevelling the wear-resistant blade with a silicon carbide or aluminium oxide abrasive, but edge setting and honing must be done with the diamonds/CBN for the lasting sharp edge; honing the wear-resistant edge with ceramic, aluminium oxide and chromium oxide compounds is the main cause of them dulling early – if you use them on your high-end knife, it may cut even worse than a good mainstream knife.
Our thorough research on that ***“Edge Rolling in High Vanadium Knives Sharpened with Aluminium Oxide versus CBN/Diamond”*** is in the Edge Stability Testing section on our website.

Since high-end blades are prone to forming the negative burr and require a certain amount of polishing, having set the edge on a #1000 CBN/diamond wheel, we hone them on rock-hard or flint-hard felt and paper wheels at a shallower than the edge angle, usually by 0.1 - 0.3 degree less in order to spare the very apex, using diamonds grit progression of 10 microns – 5 microns – 2.5 microns; and then finish the very apex with fine 0.5/0.25/0.1 micron diamonds at the exact edge angle. Typical sharpness is better than that of a production razor, under 0.1 micron edge.

STRESS FROM DEBURRING

As we've mentioned, it is crucial to know how the deburring process itself affects the residual stress. A polished edge is easier to attain by honing at high RPM on fine, leather and cotton belts, or felt and paper wheels; they are also time-effective and therefore preferred in commercial sharpening. **The high RPM honing, however, can compromise the edge retention**.

We know that steel properties in the edge change during sharpening due to the mechanical and overheating components [4], the latter causing over-tempering or detempering of the edge.

By what we've seen in our experiments and trials at the meat plants and with boning butchers, we can confidently conclude that the difference imparted by honing methods (speedy & hot versus slow & cool) matters in the initial performance of very sharp edges under 0.4 micron edge apex width; these differences level out after the first 2 hours of live cutting and/or when the sharpness drops over 0.5 micron edge apex. In other words, where very sharp edge is a requirement, the edge honing must be done slow & cool not compromising its retention.

The honing methods we've studied rank in the order of worsening the edge retention as following: Solid felt at 2850 RPM > solid paper wheel at 2850 RPM > slotted felt at 1425 RPM = slotted paper wheel at 2850 RPM > slotted paper wheel at 1425 RPM > leather, felt and paper wheels at 90 RPM having no adverse effect.
For full details see our research ***"Effect of Felt and Paper Wheel on Edge Retention"*** in the Edge Stability Testing on our website.

Scientific studies on grinding[5], interpreted for knife sharpening, tell us that the blade is not overheated if pulled across an 8-10" honing wheel at a feed rate of approximately 10 cm per 1 second on full speed grinder/buffer, and 5 cm on half-speed.

"Locating the fences" is important - this lets individual sharpeners know just how much margin they actually have not to compromise the edge retention when using powered equipment.
In our workshop we hone on rock-hard felt and leather wheels on Tormeks at 90 RPM; and on slotted rock-hard felt wheels, flint-hard felt split laps and slotted paper wheels run on half-speed buffers at 1425 RPM. Slots in the wheels cool the blade like a fan as it is honed. Trials at the meat plant have proved the edge retention is not compromised when honed our way – for details see "Proprietary 7-Carcasses Edge" section on our website.

QUALITY CONTROL

Detection of remaining burr and wire edge is an essential task in sharpening improvement. Methods to assure completeness of deburring and removal of the wire edge we have at our disposal, on the one hand, and the miniscule nature of that edge on the other, bring us to the point of contention. Where a sharpened edge scores over 100 on a BESS sharpness tester, which is 0.2 micron edge apex width, we can not tell for certain whether this is a result of a residual wire edge or correctly apexed cutting edge – because at this BESS score only microscope is able to exclude the weak apex mushrooming against the test line. Only when the BESS score taken on the standard test media line is near 50 BESS, i.e. that of uncompromised double-edge razor, we can be **absolutely** certain that the edge apex is clean of the wire edge. To the best of my knowledge, the BESS sharpness tester is the only instrumental indicator we have readily available at present.

For mainstream knives, a sharpness score of 50 to 90 BESS is a reliable indicator of a clean apex. Mainstream steels pass the check as their sharpness is tested – an edge not cleaned of micro-burr and weakened metal will not score under 100 BESS. Since the wire edge is too weak to cut the test line, it crushes on it and, as we increase the downward pressure, mushrooms against the line allowing to apply more pressure onto the widening point till the line gets finally severed. In the point of testing we see a micro-dent in the edge with the mushroomed apex displaced to the dent bottom. Yes, it is possible to hone a budget knife wire edge sharp enough to cut hair, but it will mushroom against the test line and may score even over 500 BESS on the sharpness tester; only when its apex is free of wire edge, it will score under 100 BESS.

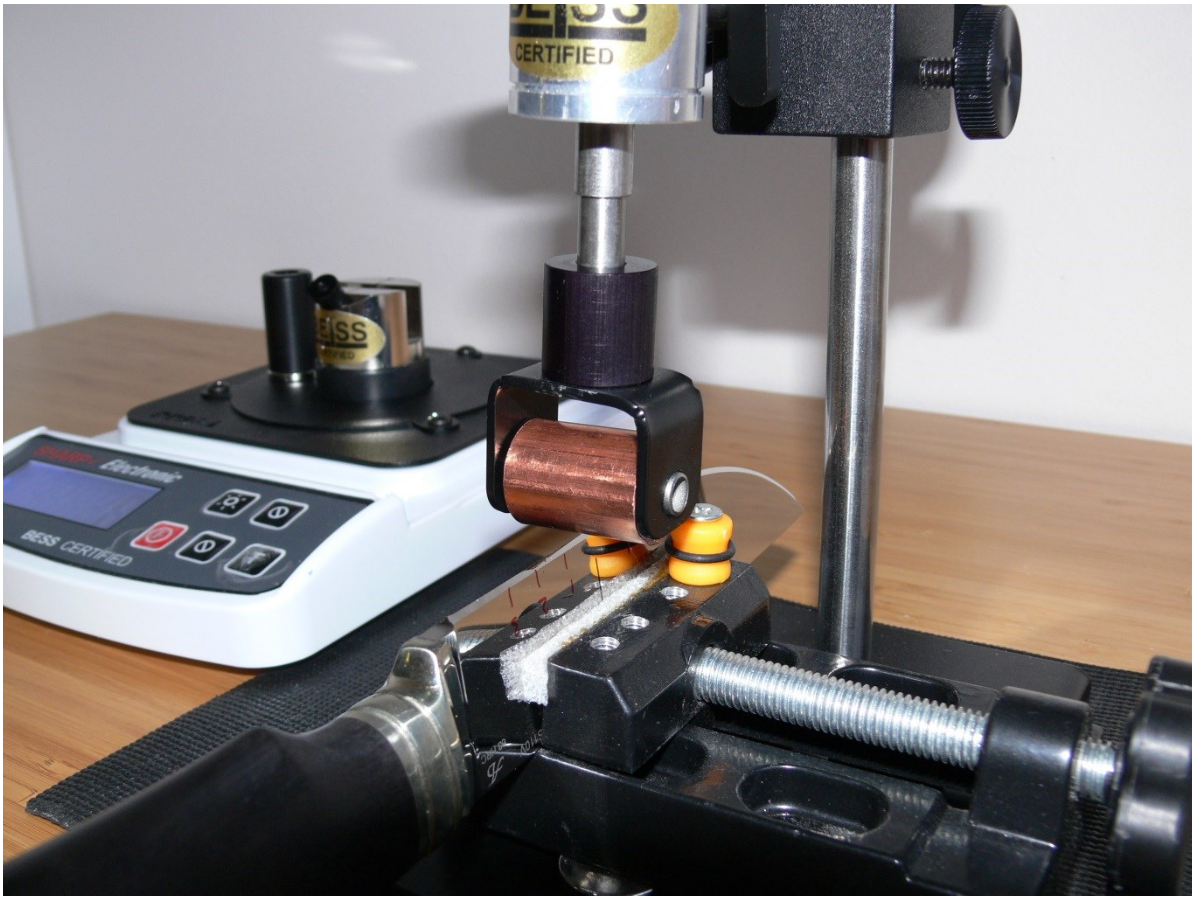
Even if you do not own a BESS sharpness tester, you can do a similar test for wire edge by push-cutting a stretched fluorocarbon fishing line, and checking with the loop if the very edge has got a micro-dent in the point of the cut – wire edge will dent, while the cleanly deburred apex will not. The fluorocarbon fishing line must be 7 LB 0.21 mm or near that.

But super-steels are different, their wire edge is capable of scoring sharpness of razors. The line of mushy metal along the apex can actually be burnished into a very sharp edge that would whittle hair. Thanks to the high-carbon excellent steel, this root burr is more like the structural continuation of the apex, rather than a common burr. Wire edge in hard quality steels may score near 50 BESS, whereas for mainstream knives such a good score is an indicator of a strong burr-free edge.

Nevertheless, there is one sign of the micro-burr and wire edge that works for all steels, and the supersteels are no exception: widely varying sharpness readings along the edge are almost always a clear indication that the root burr still remains on the edge, at least in some areas. No other sharpening flaw creates greater deviation in BESS scores than a residual micro-burr or wire edge. This stuff is often difficult to detect even in an optical microscope, you cannot feel it with your finger and cannot see it. If you learn how to detect it and how to remove it properly you will be well on the way to producing the perfect cutting edge.

Since conventional methods of micro-burr and wire edge detection don't work on high-end knives, we had to invent a test for them.

Our **Wire edge detector** detects the residual burr and spots of unstable apex that micro-crush under the light load. One forward-backward roll of the copper roller with a 150 gram load perpendicular to the edge will show **no** or less than 10 BESS worsening of sharpness on a clean robust apex, and over 20 BESS worsening of sharpness on the wire edge or a weak apex that has been shaped from micro-fractured metal deformed in sharpening.
The cut-off value for clean robust edge apex in this test is <= 10 BESS using a copper roller of diameter 3/4” and impact assembly weight 150 grams.
Full details are on our website Edge Stability Testing section.



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[4] LaTrobe Specialty Steel Company, Bulletin 104, "Improper Grinding of Tool Steels."

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