KNIFE GRINDERS

By Vadim Kraichuk

www.knifeGrinders.com.au
KG@knifegrinders.com.au
Australia

What Edge Angle is good for Supersteels

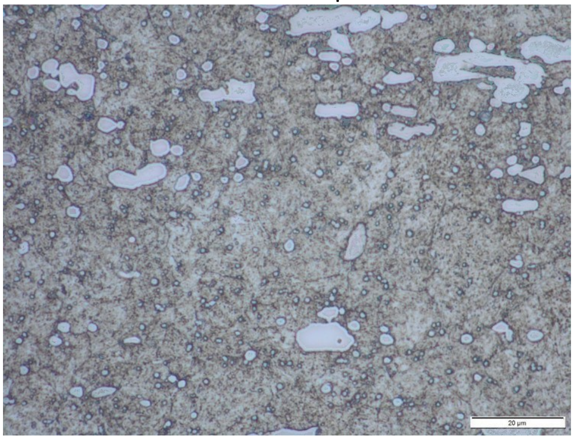
Video of the experiment: https://youtu.be/WC3oVIKhlMs
Video of the data and conclusions: https://youtu.be/eqjgeWcsHEI

The general consensus is that supersteels shall not be sharpened at the low angles of mainstream knives, because of their large carbides.

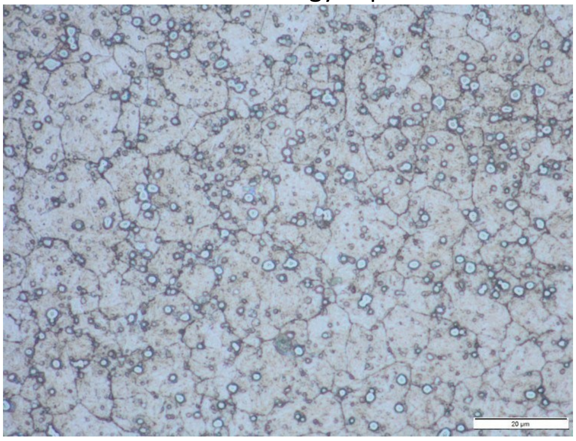
Carbides in conventional tool steels like D2 are near 20 microns in size.
Powder metallurgy forms smaller carbides, near 1 micron, but still oversized compared to the mainstream steel.

Compare micrographs of the same steel made by a conventional and powder metallurgy. The carbides (whiter particles) are finer and more uniform in the powder metallurgy version.

Conventional supersteel



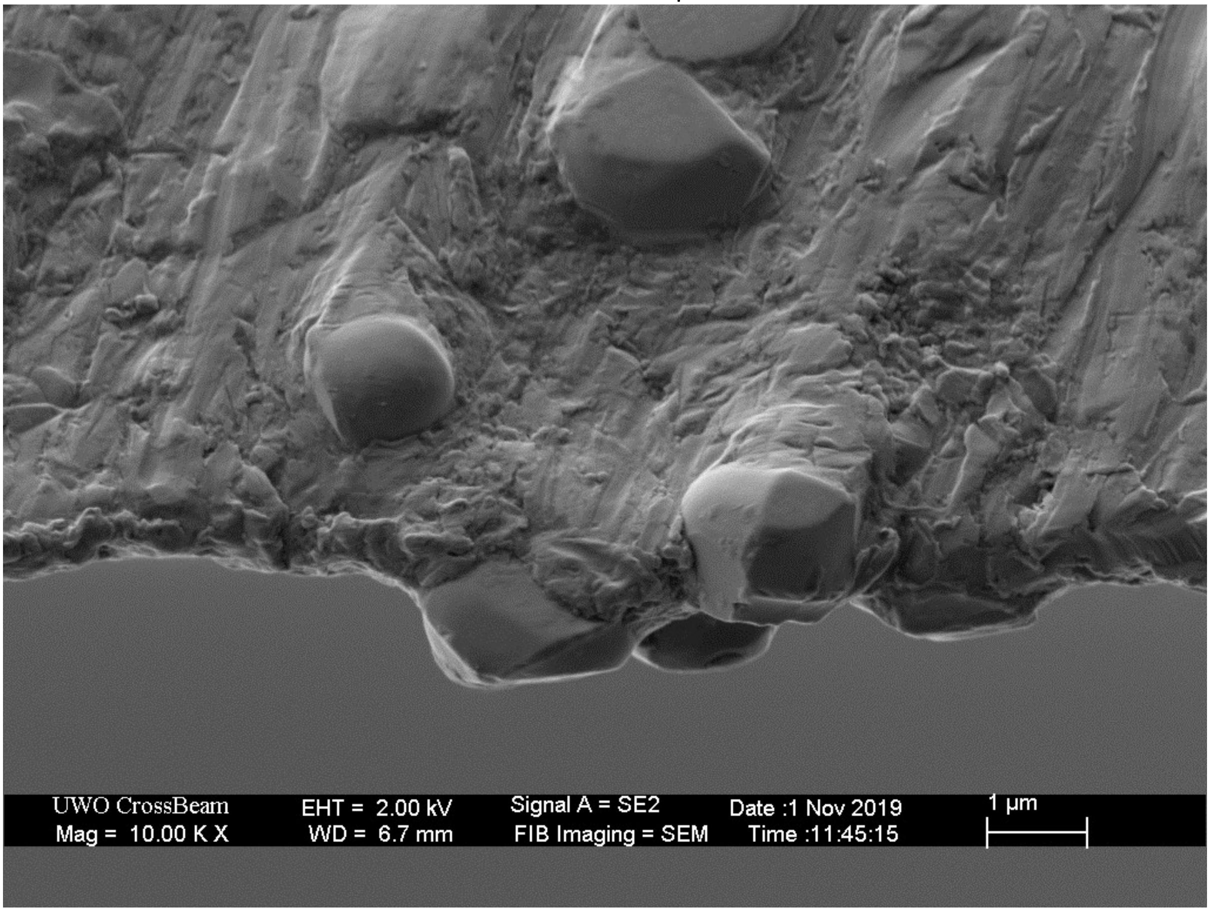
Powder metallurgy supersteel



Very sharp knives have edge of 1-2 tenths of a micron;
a dull knife has 1-micron edge and over;
and the unpolished vanadium carbides average in the modern CPM knife steels 1 micron.

Visualise those large carbides that we sharpen down to 1 tenth of micron at the edge, sitting like bolsters in the steel matrix.

SEM of Maxamet supersteel



By courtesy of Todd Simpson (scienceofsharp.com)

The lower the edge angle, the weaker is the strip of steel matrix holding them in the edge.

Steels with a larger carbide size require a greater volume of steel matrix around the carbides to keep that edge stable – and we give them a greater volume of steel by sharpening at a greater edge angle.

Modern steels that have small, near 1 micron, wear-resistant carbides, can hold a lower angle, but still not as acute as the common carbon or stainless steel.
While the conventional tool steels (e.g. D2, M4, Lohmann PGK etc) require even a more obtuse edge for stable performance.

Carbide tear-out may take place in wear-resistant steels honed with conventional abrasives, mainly in conventional tool steels with their huge 10-20 micron carbides, but not as much during sharpening as in the real cutting.

Weakening of the steel matrix during fine honing with conventional abrasives is the cause of the carbide tear-out, more pronounced in a low angle edge, e.g. in a 10 degrees per side (dps) edge as compared to 20 dps.

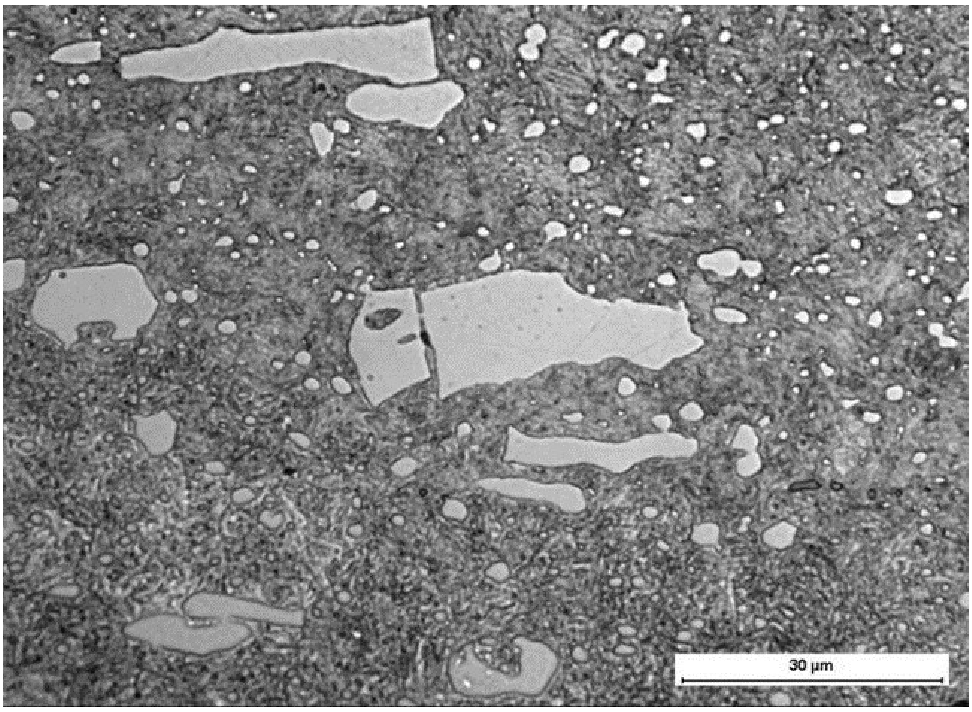
Supersteels for knife making typically have hardness near 60 HRC.
There is also a class of super-hard high speed steels (HSS) of HRC near 70: Bohler S290 Microclean, Carpenter Maxamet, Crucible Rex 121, Hitachi HAP 72 etc.

So what is the lowest stable edge angle for the supersteels?
At what degree of the edge angle goes the line of demarcation for Conventional tool steels vs Supersteels vs Superhard HSS?

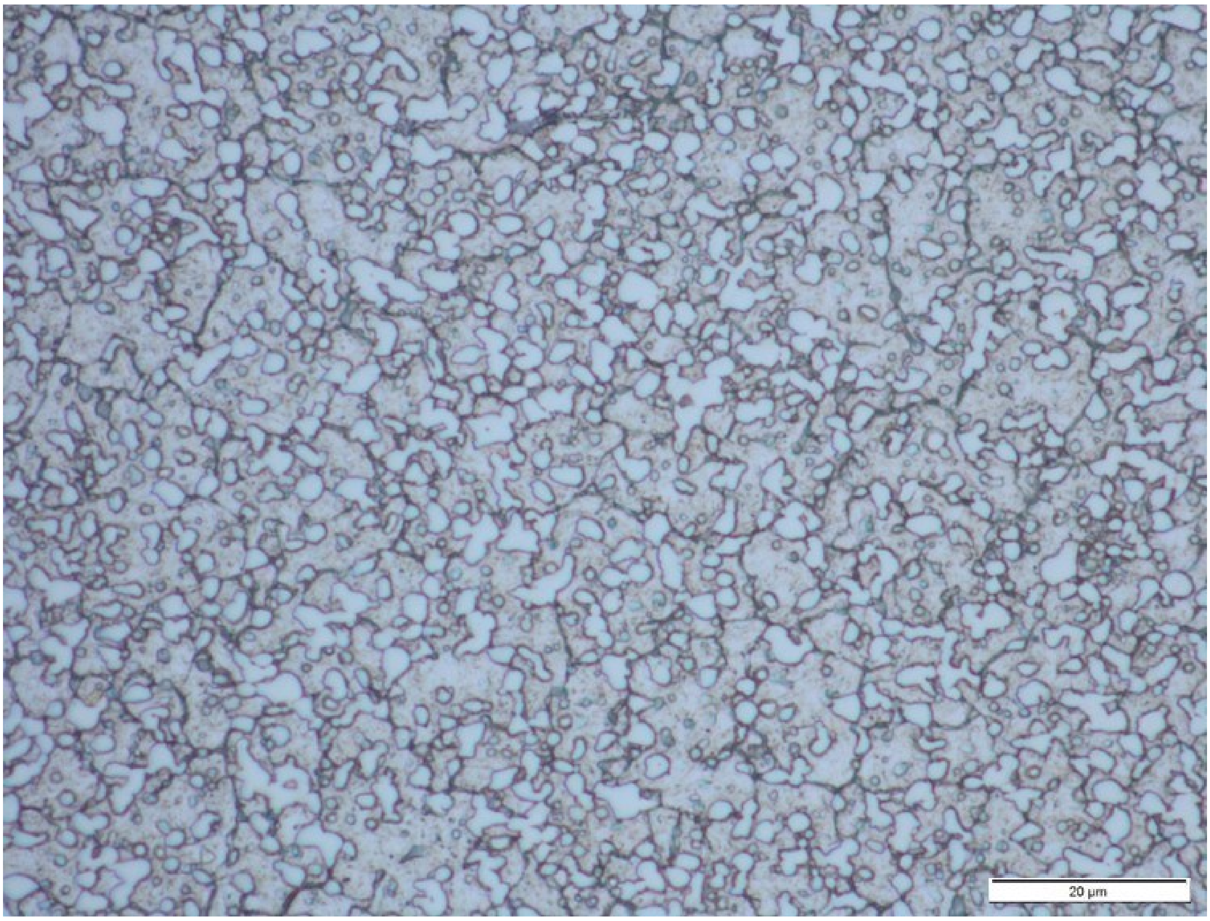
These are the knives we use in this experiment.

S290 Superhard supersteel *Custom knife* *by Andrey Birukov*	
M390 Supersteel *Custom knife* *By Christopher Berry*	
D2 Conventional tool steel *Bastinelli Raptor*	
X50CrMoV15 Mainstream stainless knife *Victorinox SWIBO*	

D2 - Conventional tool steel with huge vanadium carbides of 10 to 20 microns in size.



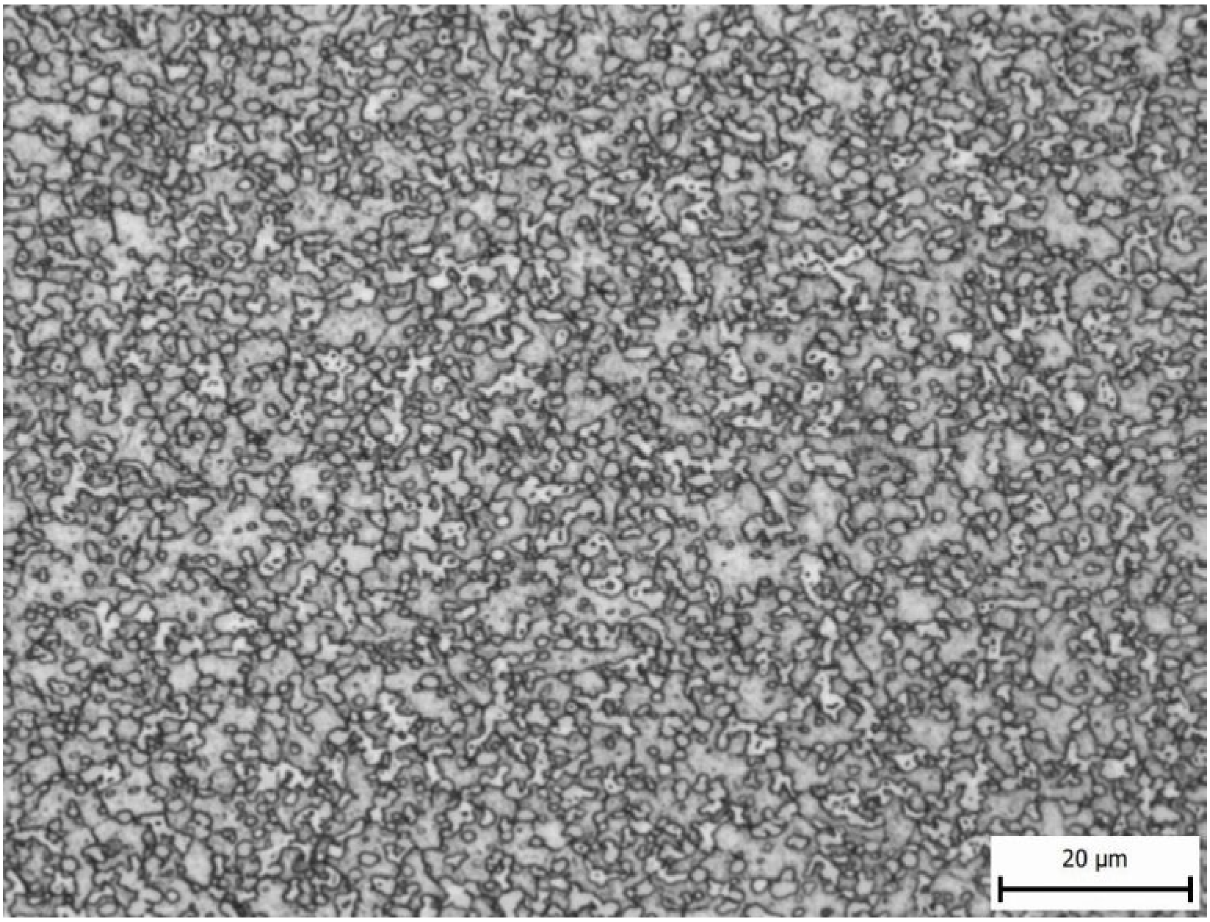
Bohler M390 is a classic powder metallurgy knife supersteel, with primary carbides near 1 micron in size



D2 and M390 have hardness of HRC 60.
Supersteels for knife making typically have hardness near 60 HRC.

There is also a special class of superhard supersteels of HRC near 70: Bohler S290 Microclean, Carpenter Maxamet, Crucible Rex 121, Hitachi HAP 72 etc.

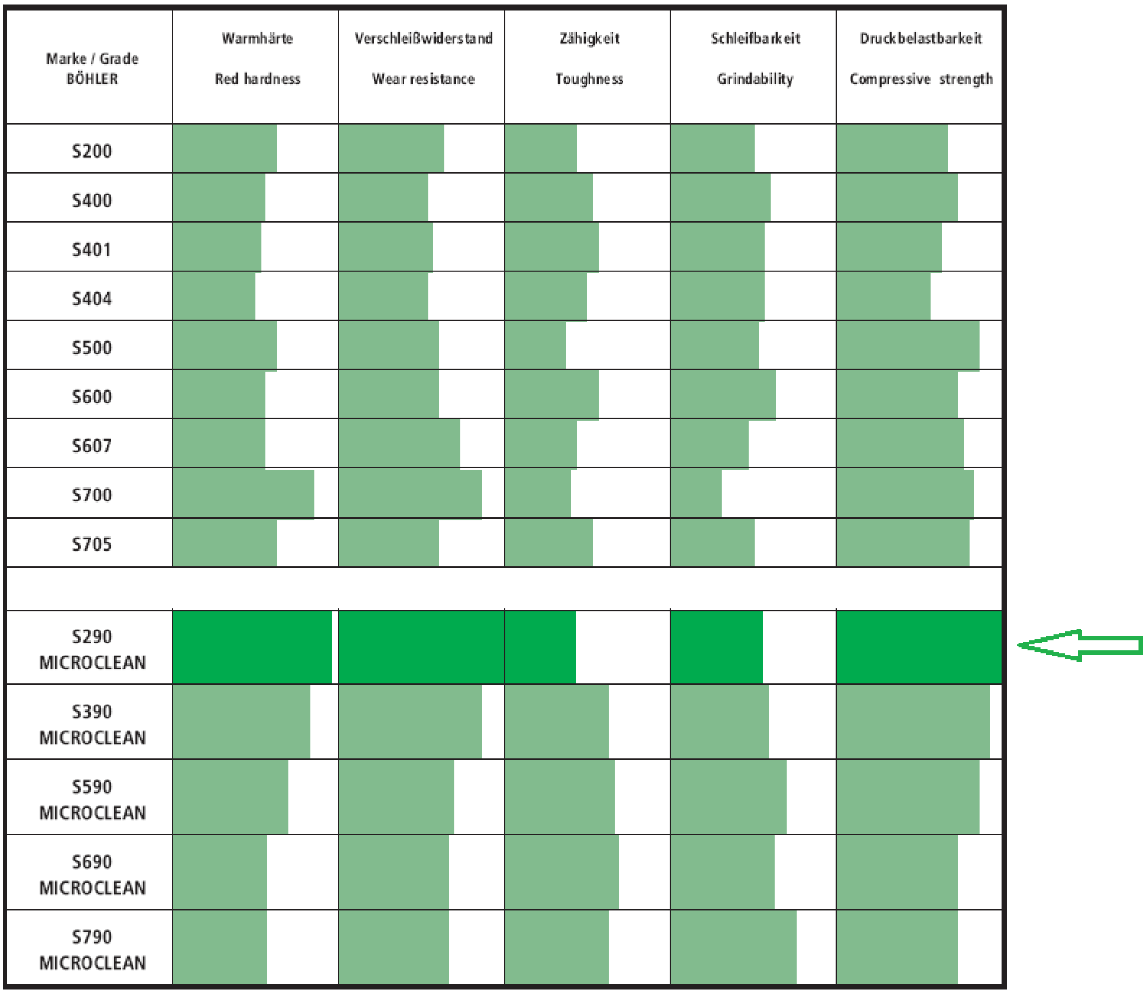
This group is represented in our experiment by the Bohler S290 Microclean



BÖHLER S290 MICROCLEAN®

Qualitativer Vergleich der wichtigsten Eigenschaftsmerkmale

Qualitative comparison of the major steel properties



The last knife steel is X50Cr15MoV - a quality stainless knife for comparison.

Steel composition

Knife Steel	HRC	C %	V %	Mo %	W %	Co %	Nb %	Cr %
S290	70	2.0	5.1	2.5	14.3	11.0	-	3.8
M390	60	1.9	4.0	1.0	0.6	-	-	20.0
D2	60	1.5	1.0	0.8	-	-	-	12
X50CrMoV15	56-58	0.5	0.15	0.6	-	-	-	15

The design of our experiment is to sharpen each of these knives at the same edge angle, from 20 to 10 dps, and subject the edge to a controlled rolling using a test stand given to us by the BESS founder Mike Brubacher, the inventor of these sharpness testers.

Structural Edge Tester (SET) is a method and device developed by Edge On Up for testing edge stability. In a nutshell, the edge is subjected to controlled rolling, the extent of which is quantified.

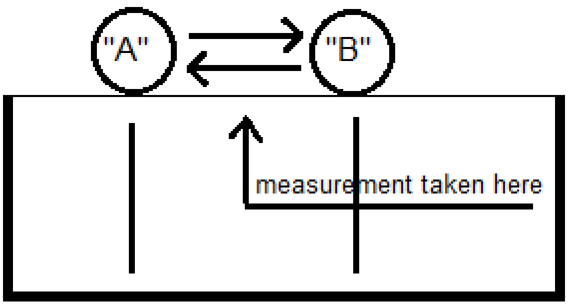
Edge sharpness tester used in the study: PT50A Industrial.

Laser protractor: CATRA Knife-Edge Protractor.

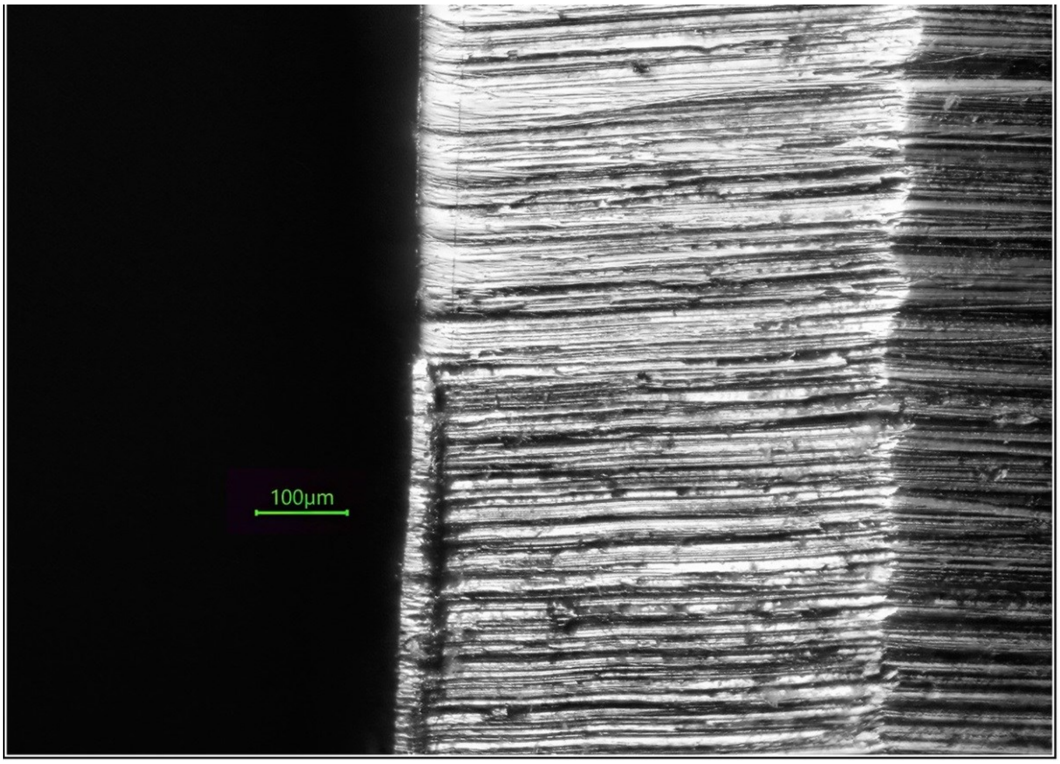
Impact cycle explained

The impact roller is a linear bearing slant at 10° to the horizontal base or in other words at 80° to the plane of the blade clamped vertically.
Standard impact assembly weight is 150 grams.

The impact roller is lowered at "A", then moved (rolled) over to "B" and then back to "A".
A-B-A is one cycle.

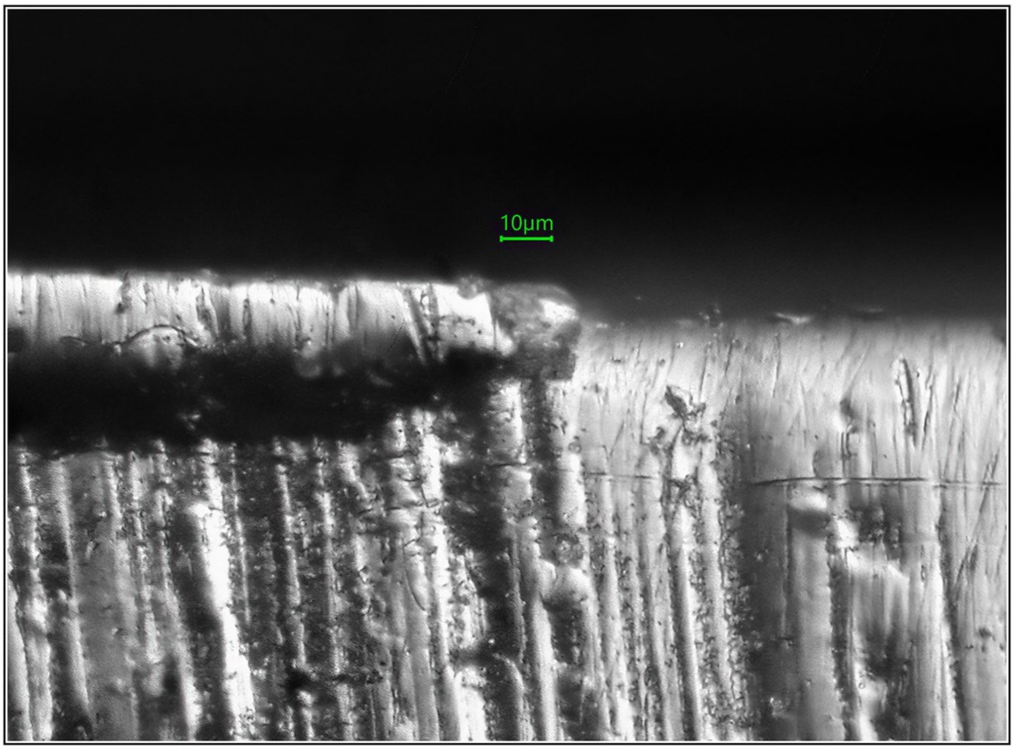


Metallurgical microscopy of the edge after a single roll by the **Structural Edge Tester** follows. Sampled is a mainstream knife subjected to 1 rolling cycle.



The microscopy by Tony Spielberg, USA

The upper portion of the micrograph shows an untouched region of the edge apex. The edge apex is lightly convex from honing.
The lower portion of the image shows where the edge has been rolled over. The rolled region has been pushed towards the viewer.



Our testing is different to the CATRA edge retention test, and manila rope cutting.
Those tests test the edge retention to abrasion.
While in our experiment we test stability of the edge to rolling, to the impact at an angle. CATRA and rope cutting test wear-resistance of the steel, while the Structural Edge Tester tests stability of the edge apex to rolling.

In real-life cutting the knife dulls through abrasion and rolling.

As Larrin Thomas has shown, there is a good correlation between the CATRA test and rope cutting tests: http://knifesteelnerds.com/2019/02/11/can-catra-predict-rope-cutting-performance

These two tests test the same thing - the wear-resistance to abrasion in perpendicular cuts.
While our tester tests the rolling component of dulling - something that the CATRA and rope cutting cannot tell.

People dealing with knives that are just working sharp tend to underestimate the role of rolling in dulling. But we deal with knives that are shaving sharp, and we are very interested in seeing the effect of rolling, because in these knives dulling through the edge rolling prevails.

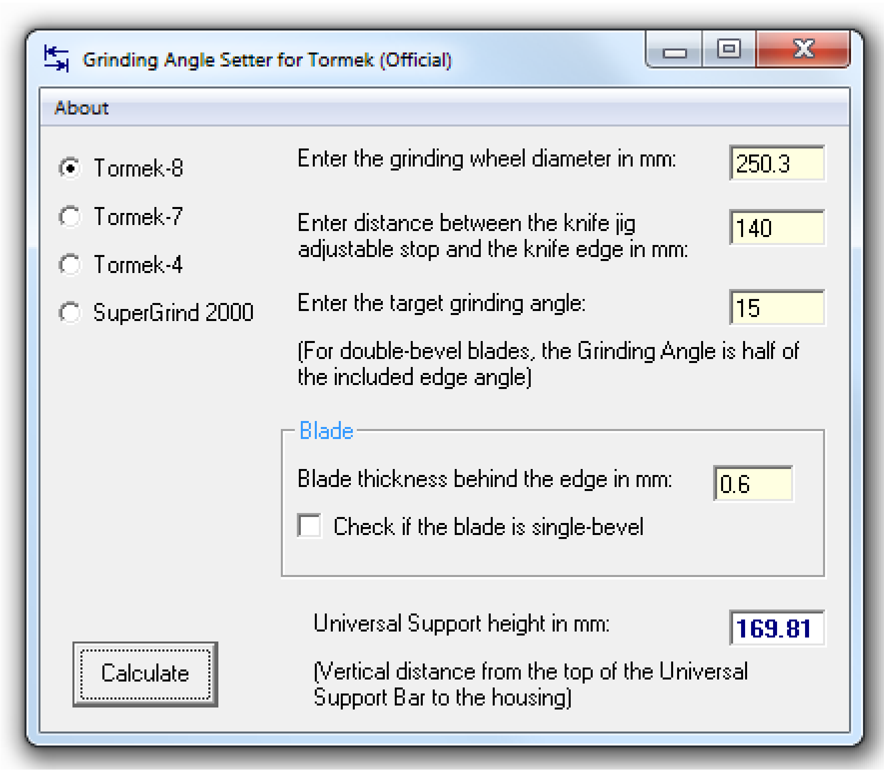
In the CATRA knife sharpness and life tester the knife is made to cut through a stack of abrasive silica paper, and the very first CATRA testing cycle abrades off the edge apex, so the CATRA tests the edge that is dull, well over 1 micron at its apex. While our tester tests the edge that is sharp, under 1 micron at its apex.

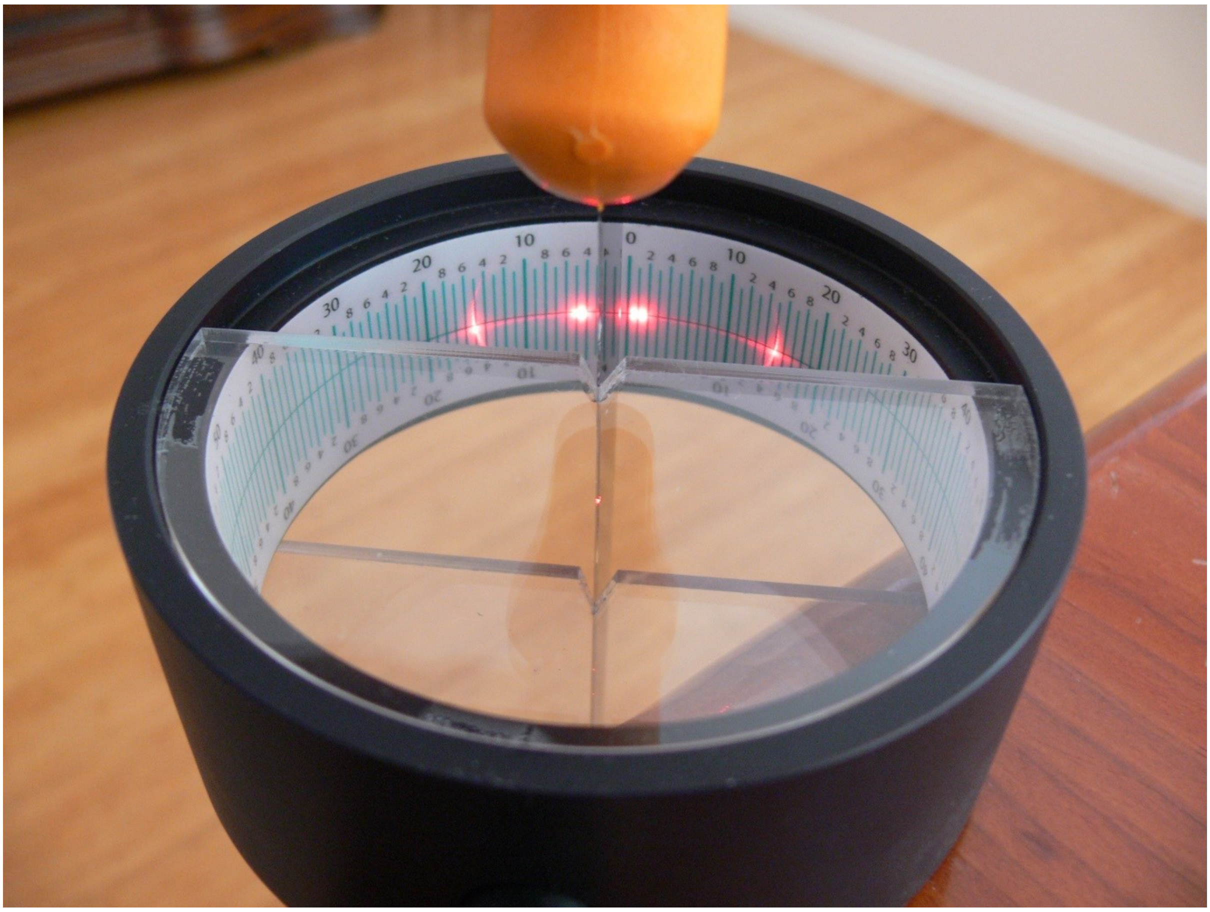
We already know by CATRA and metallurgic studies, that the super-hard S290 steel is more wear-resistant to abrasion than the M390, and the M390 is more wear-resistant than the D2 steel, and the D2 is more wear-resistant than a common stainless knife.
What we do not know is how well each of these steels withstands the rolling, and this experiment will fill in this gap in our knowledge.

The plan is to test edge stability to rolling in these 4 knives at the edge angle of 20, 17, 15, 13, 12, 11, and 10 degrees per side.

Sharpening of all 4 knives is done with the same abrasives.
Grinding is done on CBN wheels.

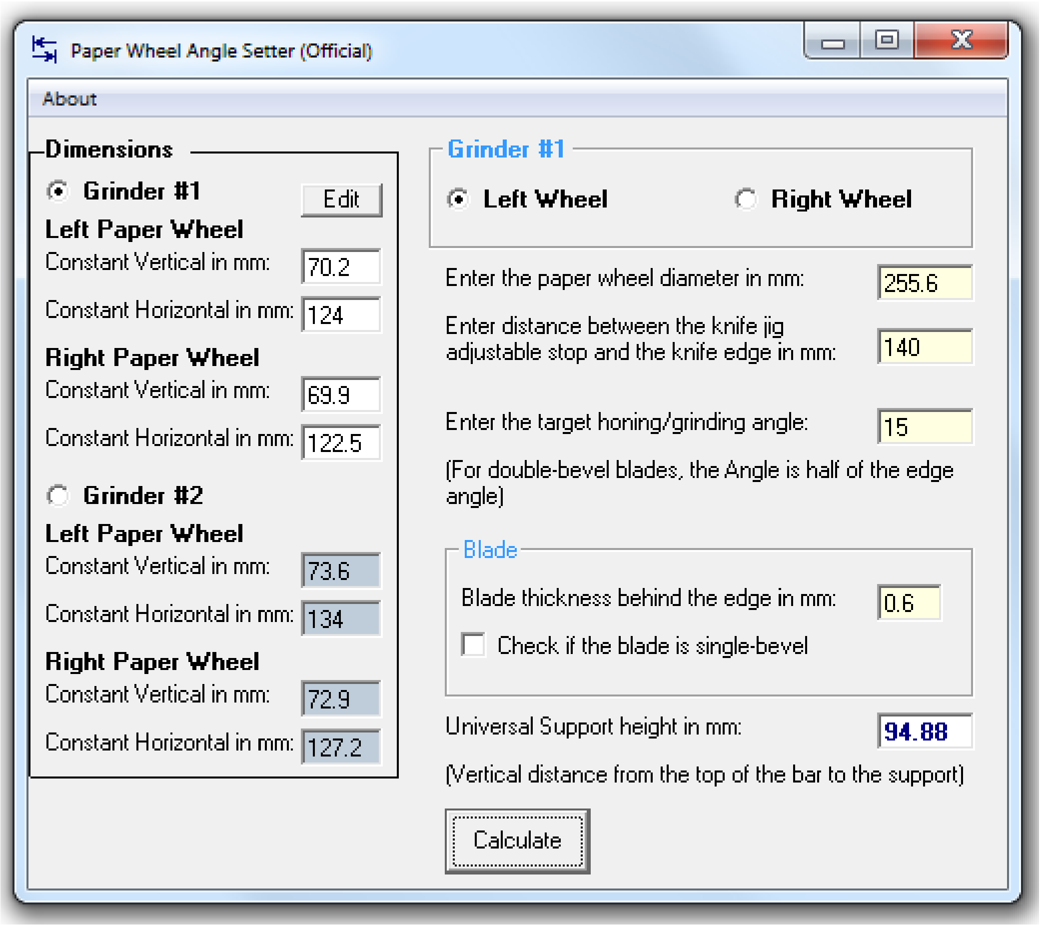
The grinding angle is controlled with our software for Tormek, and verified with a laser protractor.





Deburring and honing of all knives is done on slotted paper wheels with diamonds.

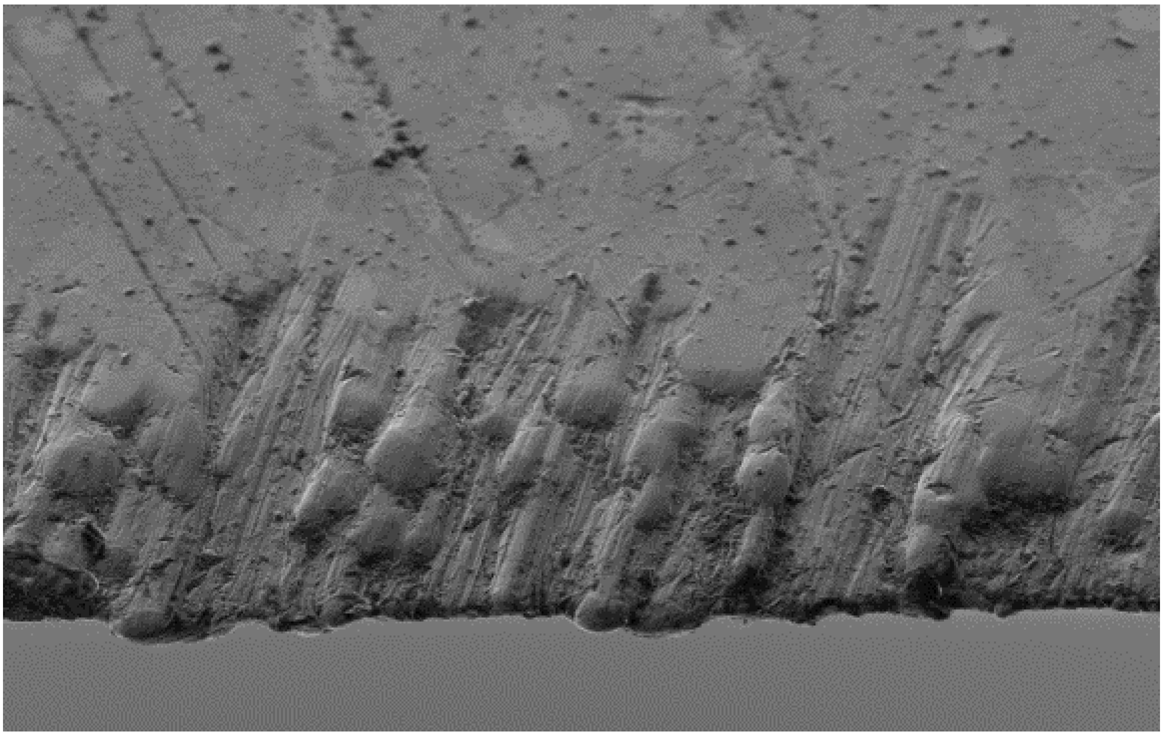
Honing angle is controlled with our software for paper wheels.



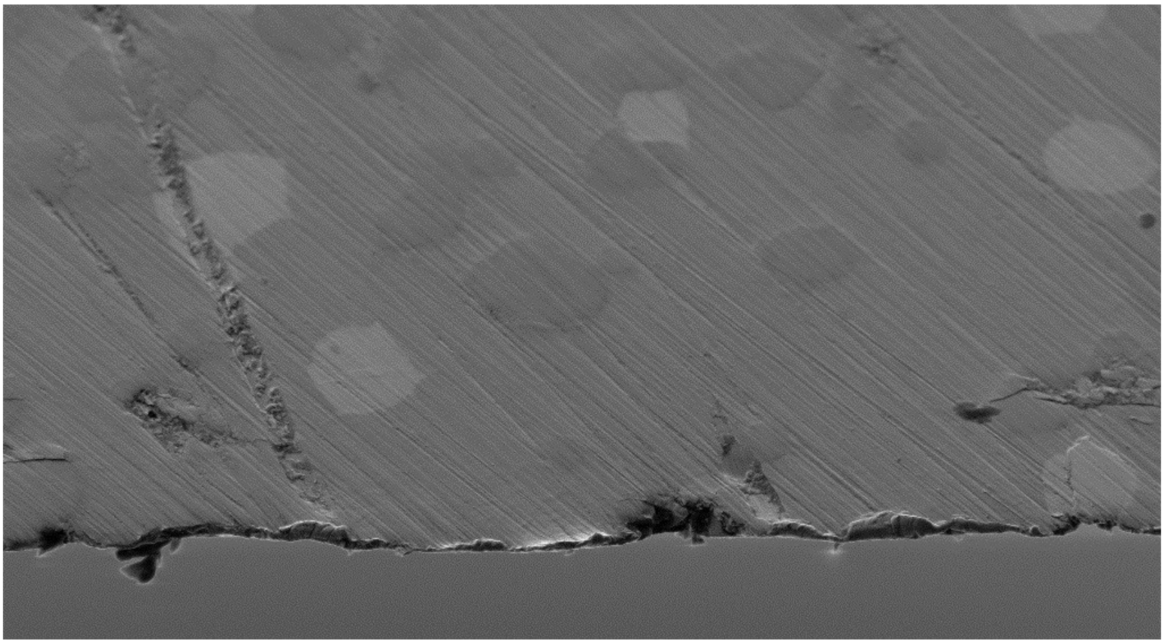
In other words, we do NOT use any aluminium oxide or silicon carbide abrasives, known to erode the steel matrix around the hard carbides and weaken the edge.
This weakening of the steel matrix in the edge is evident in SEM microscopy, and we showed that in our experiments in 2018
"Edge Rolling in High Vanadium Knives Sharpened with Aluminium Oxide versus CBN/Diamond"

Compare two SEM images of wear-resistant blades: the first edge is honed with aluminium oxide, and the second with diamonds.

Aluminium oxide erodes the iron matrix around the hard carbides



Diamonds-honed edge



Let's start with a look at the INITIAL SHARPNESS

RAW DATA

All knives sharpened with CBN #160 - #400 - #1000, and deburred/honed with diamonds:

X50CrMoV15 deburred with 5-micron diamonds, wire edge removed with 1-micron diamonds, and finished with 0.25 micron diamonds;
D2, M390 and S290 honed with 10-micron – 5-micron – 2.5-micron – 0.5-micron – 0.25-micron diamonds.

Edge angles are in degrees per side (dps).

Initial sharpness in BESS

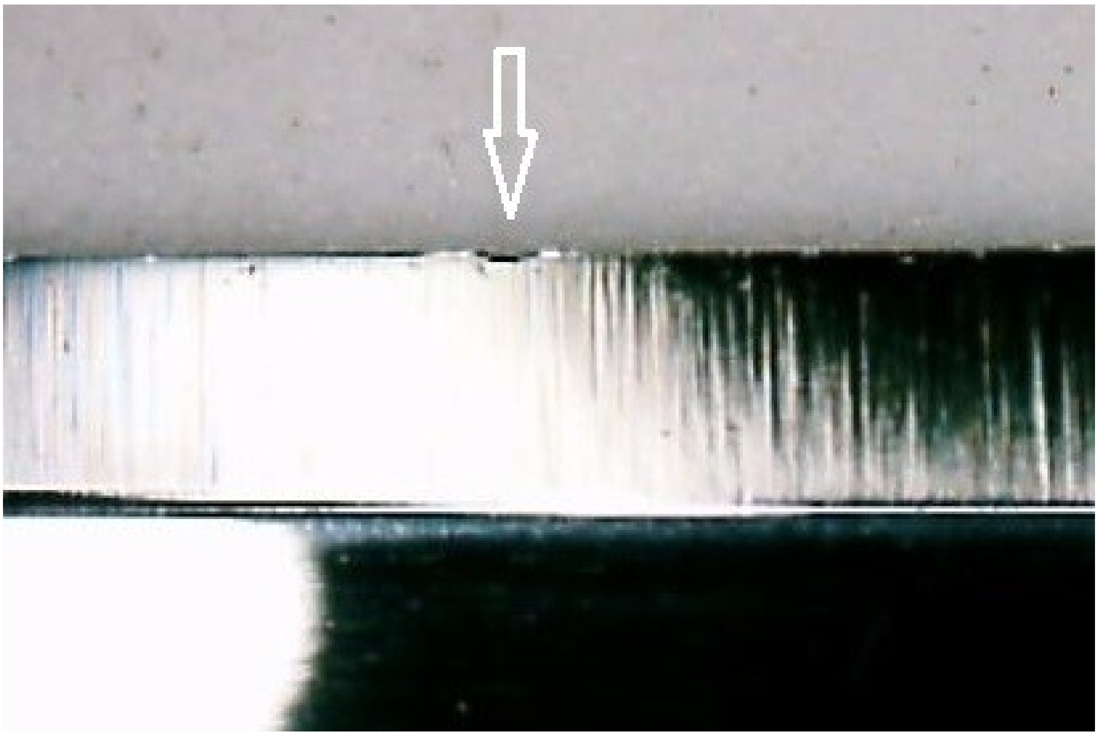
EDGE ANGLE → STEEL ↓	20°	17°	15°	13°	12°	11°	10°
S290	72	64	71	76	72	60	44
M390	92	78	78	70	85	90	86
D2	98	71	56	58	77	139	187 / 207
X50CrMoV15	90	90	84	65	45	87	545 / 811

On the BESS scale, 500 BESS and over is a dull knife, while 50 BESS is a commercial shaving razor; the lower the score, the sharper is the edge.

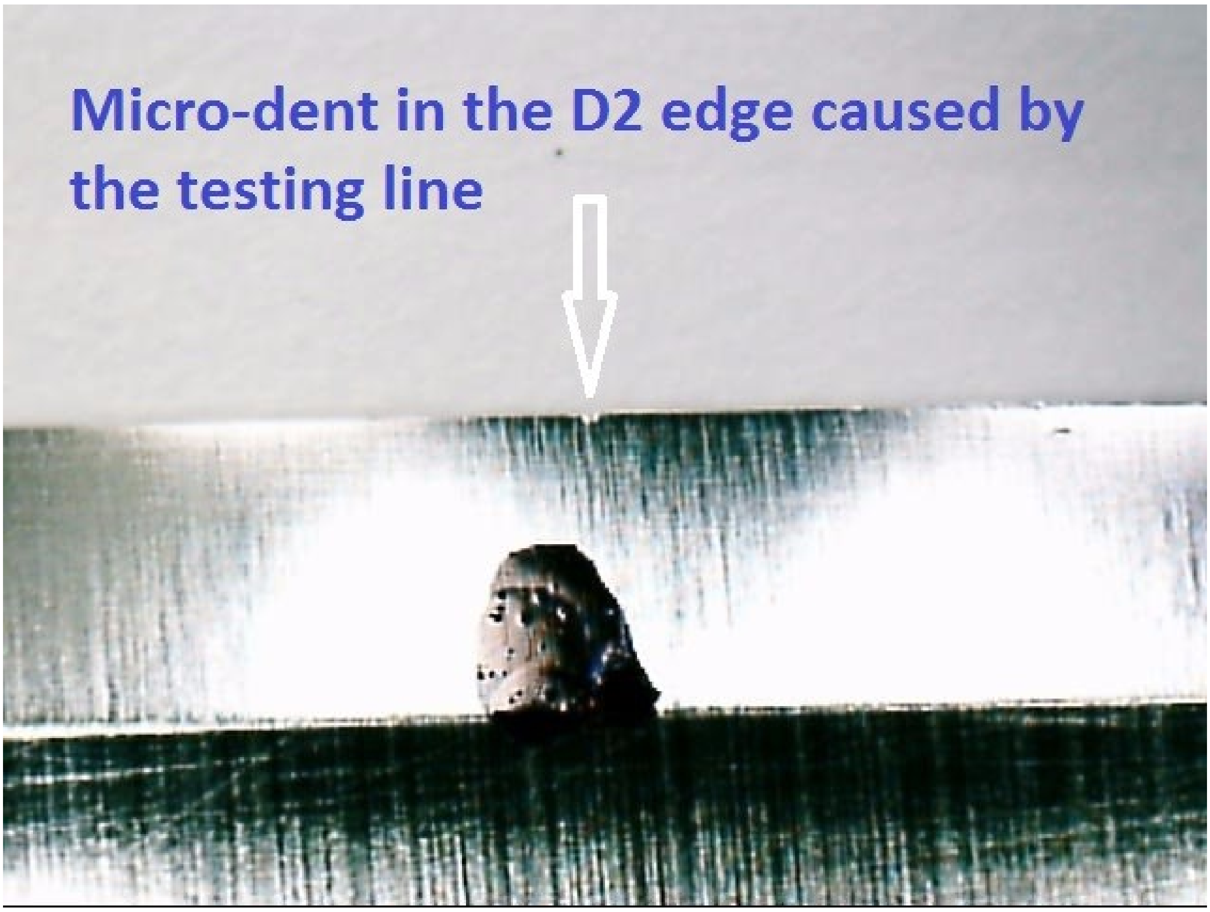
First, we see that each steel has its own edge angle, at which it comes with the best sharpness.
It is 15 dps for the D2 steel, 13 dps for the M390 supersteel, 12 dps for the mainstream knife, and 10 dps for the S290 superhard supersteel.

Next, we see that beginning with 11 dps sharpness drops in the D2 conventional tool steel.
At 10 dps sharpness of the D2 steel deteriorates further, and in the mainstream steel it becomes really bad, worse than just dull.
Microscopy shows that the testing line caused a dent in the unstable edge.

X50CrMoV15 at 10 dps – dent in the edge after testing on the sharpness tester.



D2 edge at 10 dps – micro-dent in the edge after testing on the sharpness tester.



Now the data of 1-Cycle Rolling.

BESS sharpness score after 1 roller cycle

EDGE ANGLE → STEEL ↓	Specs	20°	17°	15°	13°	12°	11°	10°
S290	Super-hard 5% V etc, HRC 70	188	205	195	210	162	213	204
M390	CPM 4% V, HRC 60	232	209	201	225	186	169	138
D2	Conventional 1% V, HRC 60	249	220	230	225	272	188	215
X50CrMoV15	Mainstream s/s HRC 57	254	308	241	235	204	267	645

Nothing unexpected here down to 12 dps.
From 20 to 12 dps we see difference in the edge stability between the supersteels and the mainstream knife.
Among the supersteels, the superhard supersteel S290 is definitely a leader in the edge stability.
M390 shows better than D2, and the D2 shows worse of all supersteels.

Yet I would call these differences marginal. What do the data from 20 to 12 dps tell us?
They tell us a counter-intuitive thing: the supersteel edge rolls at the apex almost as easy as the mainstream. Supersteels withstand abrasion much better than rolling.
It is a counter-intuitive, but firm fact shown by us and others in a number of tests.
Supersteel knives do not withstand the apex rolling much better than mainstream for the same reason that they do not hold a very sharp edge much longer than mainstream. I explain this in more detail in my Knife Deburring book, in the chapter on high-end knives.

At 11 and 10 dps, however, the picture changes.
No more clear pattern. It seems like the edge sharpness has gone bonkers.
The S290 superhard supersteel that was a clear champion, is not any more. M390 shows better than the superhard S290. The D2 shows at least as well as the S290, and even sharper.

What we see here is the positive effect of the lower edge angles on sharpness.
The lower is the edge angle, the better is sharpness – it is a commonplace.
1 roller cycle challenges the edge stability, and we see a drop in sharpness on the tester, but this is opposed by the sharpness improvement in acute edge angles.

11 degrees per side is where the acute edges win over the negatives of rolling.
10 degrees per side is where this tendency continues in supersteels, but the mainstream edge collapses.

Combination of these two opposed forces: the light rolling of the edge, and the low edge angles, gives the seemingly chaotic sharpness scores that we see at 11 and 10 degrees.

1 rolling impact causes mainly an “elastic deformation” in the edge, rather than “plastic deformation” caused by 100 rolling impacts. After 1 rolling impact the edge partially recovers, and steels that have better toughness recover better, and this recovery is more evident at the low edge angles.

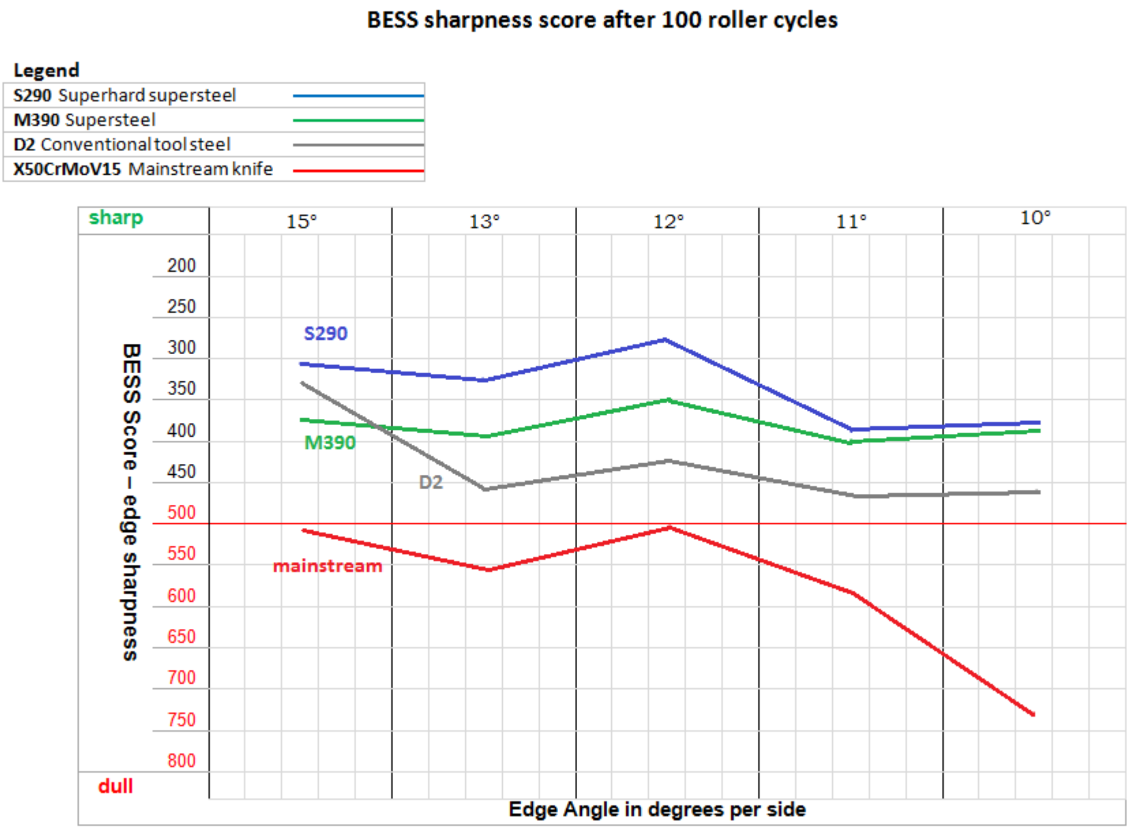
The least tough superhard S290 loses to the tougher M390 that has a “springy” edge at 11 dps.

By only 1-rolling cycle, we do not know yet how to interpret the edge stability.
Let us look at the serious impact of 100 rolling cycles.

BESS sharpness score after 100 roller cycles

EDGE ANGLE → STEEL ↓	Specs	20°	17°	15°	13°	12°	11°	10°
S290	Super-hard 5% V etc, HRC 70	-	-	307	324	286	381	376
M390	CPM 4% V, HRC 60	-	-	374	390	350	390	382
D2	Conventional 1% V, HRC 60	-	-	331	457	427	467	456
X50CrMoV15	Mainstream s/s HRC 57	-	-	512	554	505	582	733

Here you see these data put on a graph showing effect of 100 roller cycles by the edge angle.
On the graph the sharpest edges are at the top, and the dullest at the bottom.



After 100 rolling cycles the mainstream knife edge has collapsed and remains dull in all edge angles, though shows a little improvement at 12 dps.

From 13 dps, we see a clear loss of the edge stability in the D2 steel.
This tells us that conventional supersteels should not be sharpened under 15 dps.

The 15 dps shows in our experiment as the borderline of the advantage in the edge stability of conventional (ingot) supersteels over mainstream steels.

Moreover, at 15 dps, the D2 conventional steel appears to be even more stable than the M390 supersteel.

What about the S290 and M390 powder metallurgy supersteels?

They both show the best edge stability at 12 dps.

But considering that the S290 superhard steel showed the best initial sharpness at 10 dps, and still has a working edge at 10 dps after 100 rolling impacts, this may be of use in some applications.

CONCLUSIONS

Honing with diamonds/CBN allows putting a strong 12 dps edge on modern powder metallurgy supersteels that have small, near 1 micron, wear-resistant carbides.

However, we recommend not to sharpen conventional tool steels (e.g. D2, M4, Lohmann PGK etc) under 15 dps even when sharpened with diamonds/CBN – they require a 15 dps edge for stable performance.

Superhard supersteels of HRC near 70 (Bohler S290 Microclean, Carpenter Maxamet, Crucible Rex 121, Hitachi HAP 72 etc) can take and hold a very sharp edge at 10 dps, provided that they are sharpened with CBN/diamonds from start to finish.

All edges in our experiment are flat-ground to the apex (no microbevels).
The knife application determines the way we should sharpen the edge.
Consider what mechanism of dulling prevails in your area of application: rolling or abrasion.

The data we've got on the edge rolling are more pertinent to areas where the knife cuts a softer stuff, and requires high sharpness for precision and quality cuts. The preferred edge is flat-ground to the apex, i.e. the edge which cross-section is a symmetric triangle. Stability against rolling is more important in these applications.

Many people who do precise cuts do not like microbevels, and they do not like them for a reason. In our trials at the meat plant, we also tested knives sharpened with a micro-bevel - and the boning operators did not like it, they did not like the lower quality of cuts and more force in cuts.

But the data in this experiment are less pertinent to areas where knife has to cut hard and abrasive materials like cardboards, and requires only working sharpness.
Stability against abrasion is more important in these applications, and micro-bevelling may be a good option. E.g. our D2 knife can be sharpened at 10 dps for better cutting performance, and given a 15 dps micro-bevel to improve its edge stability to rolling.