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Edge Rolling in High Vanadium Knives Sharpened with Aluminium Oxide versus CBN/Diamond

PLAN

The plan is to use the SET method (Structural Edge Testing) to test edge resistance to rolling in high vanadium knives with vanadium content ranging from 1% to 10%, sharpened with Aluminium Oxide versus Cubic Boron Nitride (CBN) & diamond abrasives.

The goal is to obtain experimental data for the ongoing discussion among knife enthusiasts whether sharpening high vanadium knives with abrasives other than CBN and diamond enhances their edge propensity to rolling.
There is no smoke without fire, and the more people own high-end knives, the more we hear about this. The most plausible explanation is that the common abrasives weaken steel matrix around the vanadium carbides – being too soft for the vanadium carbides they only abrade the steel around the vanadium carbides rather than polish them.

A priori expectation is that we will see no significant difference in edge rolling before some threshold content of vanadium. Obvious practical application would be to allow the common abrasives for sharpening steels with lower than that vanadium content, and use exclusively CBN and diamond for higher.

Vanadium carbides are not the only high wear resistant carbides - niobium, cobalt, molybdenum and wolfram (tungsten) carbides also are, and should respond similarly to abrasives.

SET METHOD

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.

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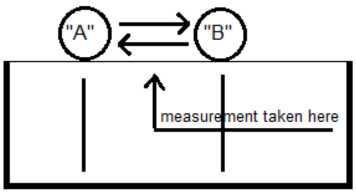
<u>Impact cycle explained</u>

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.

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See our video on YouTube https://youtu.be/EdGOSWjrM0E

Our standard SET testing procedure is to measure edge sharpness after every cycle for the first 5 cycles (Phase I), then after every 5 cycles to 50 cycles (Phase II), and then (i.e. from the 50th to 100th cycles) after every 10 cycles (Phase III).
Where by the 100th cycle the edge hasn't blunted to 500 BESS, we continue rolling, measuring sharpness every 20 cycles till reach 500 BESS.

Sharpness of the majority of knives (apart from CPM "supersteels") nears or exceeds 500 BESS, i.e is rendered blunt, by the 100^{th} impact cycle, allowing us to watch the full **life cycle** of the edge within one 11-minute test.

The testing procedure yields additional information about events happening in the edge through the three distinctive phases:

- **Phase I** "Elastic deformation" from the 1^{st} to the 5^{th} impact cycle, when sharpness is measured after every cycle – considering that interval between subsequent impact cycles is about 30 sec, this break in impact allows the edge to partially recover from rolling. This phase takes about 2.5 min.

- **Phase II** "Elasto-Plastic transition" from the 6^{th} to 50^{th} impact cycle, where the edge gets 5 impact cycles between sharpness measurements – edge is challenged for resistance to plastic deformation. The elastic deformation transits to plastic here. Weaker steels simply crash in this phase. This phase takes 5 min.

- **Phase III** "Plastic deformation" from the 51^{st} to 100^{th} impact cycle, where the edge is continuously rolled 10 times before each next sharpness measurement, testing the edge stability to permanent rolling. This phase takes about 3.5 min.

Key indicators:

- Overall average sharpness over 100 impact cycles;
- Average sharpness in the Phase I (elastic deformation) - calculated as an average of sharpness scores in the first 5 impact cycles;
- Sharpness by the end of the Phase II (elasto-plastic transition) – calculated as an average of 3 sharpness scores: after 40, 45 and 50 impact cycles;
- Number of impact cycles to turn the edge blunt at 500 BESS (resistance to permanent rolling).

Overall, each SET test takes 11 minutes to estimate life cycle of the edge.

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SELECTION OF KNIVES

For the purpose of a comparable selection, we selected steels with minimum content of other than Vanadium alloys. The table below illustrates how we picked steels from the knives in our disposal – those in bold were selected for this research.

Knife Steel	HRC	Vanadium %	C %	Mo %	W %	Co %	Nb %	Cr %
Vanadis 10	63	**9.8**	2.9	1.5	-	-	-	8.0
S110V	63	9.0	2.8	2.3	-	2.5	3.0	15.3
Vancron 40	64	8.5	1.1	3.2	3.7	-	-	4.5
S290	70	5.1	2.0	2.5	14.3	11.0	-	3.8
M390 or **CPM20CV**	60	**4.0**	1.9	1.0	0.6	-	-	20.0
S30V	60	4.0	1.4	2.0	0.4	-	-	14.0
S35VN	60	3.0	1.4	2.0			0.5	14.0
Elmax	62	**3.0**	1.7	1.0	-	-	-	18.0
Lohmann PGK	62	**2.0**	1.2	1.5	1.5			8.2
D2	60	**1.0**	1.5	0.8	-	-	-	12

Selected Knives

Steel	V %		
Vanadis 10	9.8	Custom knife, Russia 	
CPM20CV	4.0	Survive Knives GSO 4.1, USA 	
Elmax	3.0	Custom knife, Russia 	
Lohmann PGK	2.0	Kizlyar Supreme Dominus, Russia 	
D2	1.0	Ka-Bar D2 Extreme, USA 	

As a **CONTROL TEST**, to see if the sharpening abrasive as such imparts any difference, we sharpened in the same way a vanadium-free but high-carbon knife in SR-101 steel (Busse Swamp Rat knife), its chemical composition follows.

Knife Steel	HRC	Vanadium %	C %	Mo %	W %	Co %	Nb %	Cr %
SR-101	57-59	-	1	-	-	-	-	1.5

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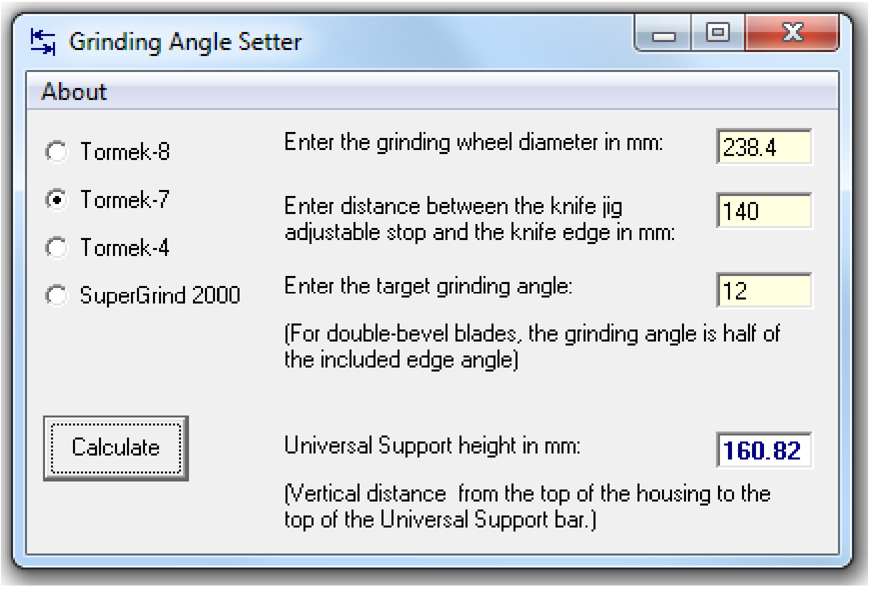
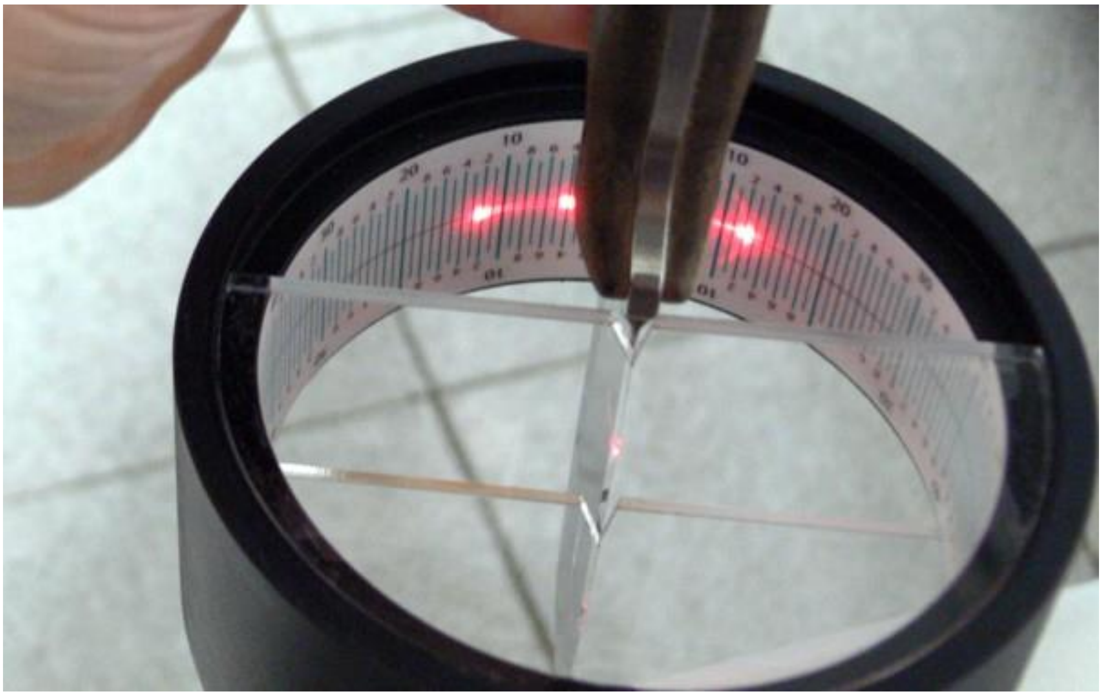
SHARPENING METHOD

We know from our previous SET tests that the results depend on the edge angle and initial sharpness.

All knives were sharpened and honed the same way on Tormek T-7 and T-8 machines at the same edge angle of 12 degrees per side (24° included) and to the same sharpness within 80-100 BESS. Sharpness of 100 BESS is midway between safety razors and utility blades; for those new to BESS - the lower the score, the sharper is the edge, e.g. a safety DE razor scores 50 BESS, and utility blades 150-200 BESS.

Edge angle was ground with the help of [our computer software for Tormek] and verified with a CATRA laser protractor.





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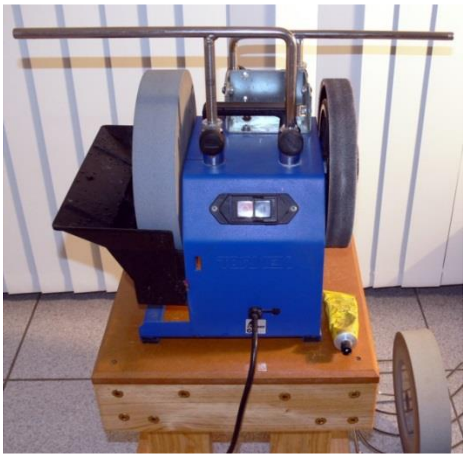
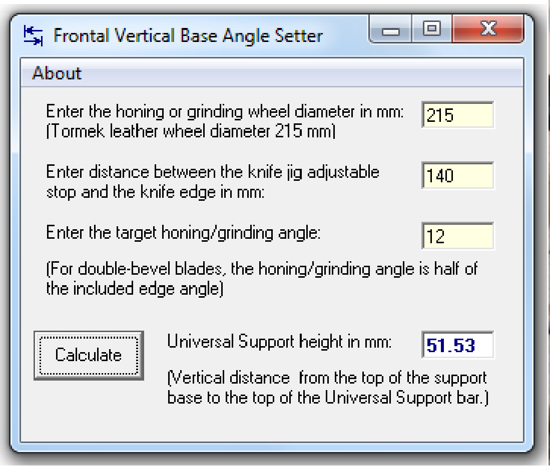
The first sharpening was made with Tormek stock 250 mm aluminium oxide wheels, and honing on the Tormek leather wheel with the Tormek honing paste, known to be chiefly of aluminium oxide particles averaging 3 microns in size.
Edge bevel was ground on a freshly trued SG-250 wheel (#220), and edge set on a dedicated SG-250 wheel graded to #1000 with a diamond plate.



grading to grit #1000

Honing angle was controlled with our [FVB for Tormek-7 and computer software](#).
First round of SET testing was run on these knives.



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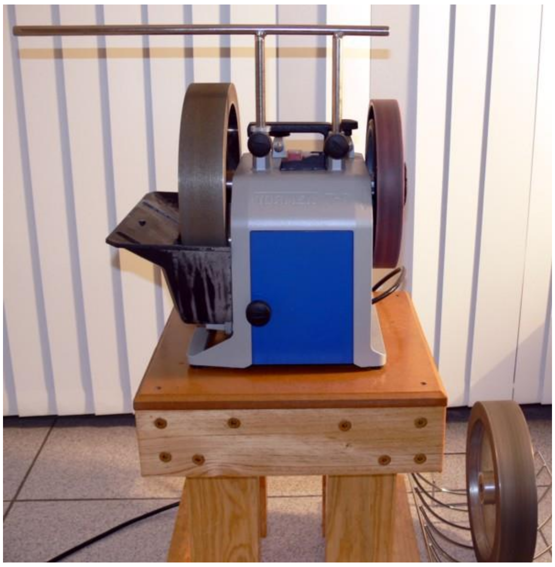
The same knives were then re-sharpened on Tormek-compatible 254 mm CBN wheels, and honed on a dedicated Tormek leather wheel impregnated with 3-micron diamonds.
Edge bevel was ground on a CBN wheel #400, and edge set on a CBN wheel #1000.
For honing on Tormek with diamonds we normally use a rock-hard felt wheel, but this time used the leather wheel to hone the same way as in the first sharpening.
Second round of SET testing was then run.



To match sharpening done with aluminium oxide and CBN/diamond, in each sharpening we set the edge with 2 passes on the #1000 aluminium oxide or CBN wheel, and were giving the edge the same amount of honing of 2-3 slow passes across the leather wheel, alternating sides.

With this setup, in sense of achievable sharpness I didn't find aluminium oxide much inferior to CBN or diamonds in sharpening high vanadium steels, though definitely slower in bevelling – having ground the edge angle on a coarse SG wheel, we set the edge with two passes alternating sides on the SG wheel graded to the grit #1000, and honed/deburred with 2-3 slow passes on the leather wheel with the Tormek honing paste – in all cases the sharpness we got was within 80-100 BESS.
It was faster to bevel the edge angle on a coarse CBN wheel, but by setting the edge with the same two passes on the grit #1000 CBN wheel and honing with 2-3 passes on the leather wheel with 3-micron diamonds we were getting the same sharpness.

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DATA

Data numbers in the charts is the number of the impact roller cycles with the resultant sharpness. E.g. " *x1 = 250, x2 = 300* " means after 1 impact cycle the edge sharpness is 250 BESS, after 2 cycles 300 BESS, and so on.

All knives are sharpened at an edge angle of 12 dps, to initial sharpness near 100 BESS.

ABRASIVE → STEEL ↓	Aluminium Oxide	CBN/Diamond
Vanadis 10 **V 9.8 %** HRC 63	x1=243 x2=266 x3=265 x4=305 x5=312 x10=317 x15=339 x20=380 x25=355 x30=410 x35=403 x40=404 x45=416 x50=451 x60=489 x70=489 x80=490 x90=476 x100=451 x120=468 x140=522	x1=203 x2=206 x3=234 x4=268 x5=302 x10=292 x15=323 x20=348 x25=330 x30=358 x35=372 x40=409 x45=386 x50=361 x60=380 x70=389 x80=425 x90=374 x100=453 x120=411 x140=412 x160=410 x180=408 x200=418 x220=389 x240=377 x260=446 x280=434 x300=412 x320=464 x340=494 x360=463 x380=529
CPM20CV **V 4.0 %** HRC 60	x1=275 x2=282 x3=297 x4=303 x5=328 x10=331 x15=324 x20=375 x25=401 x30=391 x35=423 x40=436 x45=443	x1=215 x2=196 x3=208 x4=259 x5=275 x10=312 x15=317 x20=347 x25=354 x30=349 x35=371 x40=427 x45=384

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	x50=450 x60=437 x70=411 x80=479 x90=464 x100=449 x120=506	x50=394 x60=416 x70=438 x80=449 x90=456 x100=457 x120=459 x140=478 x160=483 x180=471 x200=495 x220=508
Elmax **V 3.0 %** HRC 62	x1=264 x2=290 x3=345 x4=369 x5=395 x10=402 x15=458 x20=487 x25=500 x30=495 x35=545 x40=558 x45=533 x50=607 x60=622 x70=605 x80=641 x90=618 x100=683	x1=221 x2=213 x3=246 x4=245 x5=277 x10=288 x15=312 x20=317 x25=373 x30=413 x35=380 x40=402 x45=446 x50=430 x60=455 x70=418 x80=410 x90=429 x100=482 x120=468 x140=514
Lohmann PGK **V 2.0 %** HRC 62	x1=257 x2=275 x3=300 x4=289 x5=315 x10=361 x15=347 x20=382 x25=429 x30=413 x35=464 x40=498 x45=464 x50=499 x60=502 x70=544 x80=591 x90=519 x100=545	x1=280 x2=313 x3=271 x4=357 x5=344 x10=342 x15=377 x20=366 x25=449 x30=416 x35=461 x40=458 x45=403 x50=482 x60=495 x70=484 x80=450 x90=419 x100=525
D2 **V 1.0 %** HRC 60	x1=263 x2=292 x3=317 x4=337	x1=216 x2=323 x3=340 x4=349

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	x5=353 x10=398 x15=440 x20=478 x25=494 x30=495 x35=496 x40=478 x45=520 x50=534 x60=585 x70=602 x80=605 x90=616 x100=559	x5=328 x10=341 x15=359 x20=376 x25=400 x30=402 x35=428 x40=424 x45=434 x50=477 x60=493 x70=494 x80=506 x90=532 x100=563
CONTROL SR-101 **V 0%** HRC 57-59	x1=279 x2=299 x3=337 x4=372 x5=375 x10=421 x15=470 x20=498 x25=532 x30=523 x35=520 x40=540 x45=567 x50=565 x60=622 x70=632 x80=665 x90=612 x100=666	x1=241 x2=235 x3=292 x4=315 x5=343 x10=387 x15=416 x20=428 x25=464 x30=507 x35=474 x40=514 x45=510 x50=480 x60=551 x70=630 x80=570 x90=711 x100=602

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Key Indicators

KEY INDICATOR → STEEL ↓	Vanadium	Average sharpness over 100 cycles		Average sharpness in the Phase I (elastic deformation)		Sharpness by the end of the Phase II (elasto-plastic transition)		Number of impact cycles to turn the edge blunt at 500 BESS (resistance to permanent rolling)	
		Alum. Oxide	CBN/diamond	Alum. Oxide	CBN/diamond	Alum. Oxide	CBN/diamond	Alum. Oxide	CBN/diamond
Vanadis 10	**V 9.8 %**	382	338	278	243	424	385	140	380
CPM20CV or M390	**V 4.0 %**	384	348	297	231	443	402	120	220
Elmax	**V 3.0 %**	496	356	333	240	566	426	25	140
Lohmann PGK	**V 2.0 %**	421	405	287	313	487	448	60	100
D2	**V 1.0 %**	466	410	312	311	511	445	45	80
CONTROL SR-101	-	500	456	332	285	557	501	25	30

PERCENTAGE DIFFERENCE in sharpness between the CBN/Diamond and Aluminium Oxide

(% of better sharpness of CBN/Diamond vs Aluminium Oxide)

KEY INDICATOR → STEEL ↓	Vanadium	Average sharpness over 100 cycles	Average sharpness in the Phase I (elastic deformation)	Sharpness by the end of the Phase II (elasto-plastic transition)	Number of impact cycles to turn the edge blunt at 500 BESS (resistance to permanent rolling)
Vanadis 10	**V 9.8 %**	13%	14%	10%	171%
CPM20CV or M390	**V 4.0 %**	10%	29%	10%	83%
Elmax	**V 3.0 %**	**39%**	**39%**	**33%**	**460%**
Lohmann PGK	**V 2.0 %**	4%	-8%	9%	66%
D2	**V 1.0 %**	14%	0%	15%	78%
CONTROL SR-101	-	10%	17%	11%	20%

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3% VANADIUM PHENOMEN

"Curiouser and curiouser!" as said Alice in Wonderland.

Numbers tell us that edge rolling does depend on whether we sharpen with aluminium oxide or CBN/diamond, and CBN/diamond gives better lasting sharpness than aluminium oxide, but correlation with the vanadium content is not linear – instead, there is a dramatic rolling in edges with vanadium content of 3% sharpened with aluminium oxide.

DATA INTERPRETATION AND CONCLUSIONS

Control 0% vanadium (SR-101) – the control test shows some improvement in edge resistance to rolling when CBN/diamond abrasives are used, which is interesting in itself, however the main thing it gives us for the purpose of this research is the baseline difference between the CBN/diamond and aluminium oxide abrasives, so that any numbers less-than-or-equal-to are not related to alloys composition.

Vanadium 1% (D2) - CBN/diamond abrasives moderately improve sharpness over aluminium oxide, with no difference in the initial period.

Vanadium 2% (PGK) - CBN/diamond abrasives have little to no advantage over aluminium oxide, seen only in somewhat prolonged edge life; initially the edge sharpened on aluminium oxide shows even better elasticity and sharpness (Phase I).

Vanadium 3% (Elmax) - CBN/diamond abrasives show high advantage over aluminium oxide, the edge stays sharp by 4 times longer. In saying so we are talking in relative terms, and positive effect of the CBN/diamond as such is not that much different from its neighbours of 2% and 4% vanadium (as seen by absolute sharpness scores) – it is the aluminium oxide worsened edge retention that makes the numbers so high.

Vanadium 4% (CPM20CV or M390) - CBN/diamond abrasives have moderate advantage over aluminium oxide, clearly noticeable both in the initial period and prolonged life of the edge.

Vanadium 9.8% (Vanadis 10) - CBN/diamond abrasives have moderate to high advantage over aluminium oxide, the working edge lasts 1.5 times longer.

3% vanadium is the threshold content, where sharpening with CBN/diamond becomes preferred over common abrasives.

The following hardness graph shows why the common abrasives like aluminium oxide may weaken steel matrix around the vanadium and alike wear-resistant carbides.

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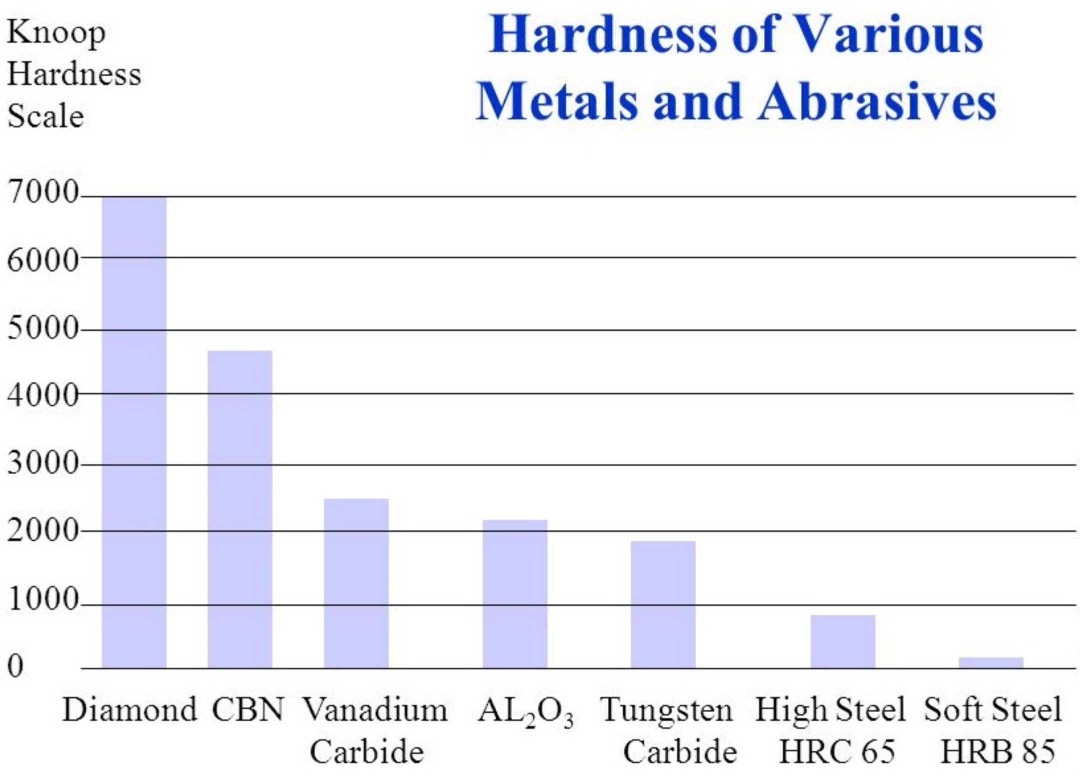

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In the below charts we compare SET data of knives from this and our previous research sharpened at 12 degrees to initial sharpness of about 100 BESS, using CBN/diamond abrasives.
Results are sorted from the best (at the top) to the worst.

KEY INDICATOR → STEEL ↓	**Average sharpness over 100 cycles**	**Number of impact cycles to turn the edge blunt at 500 BESS** (resistance to permanent rolling)	**Sharpness by the end of the Phase II** (elasto-plastic transition)
Vanadis 10	338	380	385
CPM20CV or M390	348	220	402
Elmax	356	140	426
Lohmann PGK	405	100	448
D2	410	80	445
SR-101	456	30	501
Global	475	45	523
x45CrMoV15	486	35	536

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Steel composition: HRC, Carbon and wear-resistant alloys

Knife Steel	HRC	C %	V %	Mo %	W %	Cr %
Vanadis 10	63	2.9	9.8	1.5	-	8.0
CPM20CV or M390	60	1.9	4.0	1.0	0.6	20.0
Elmax	62	1.7	3.0	1.0	-	18.0
Lohmann PGK	62	1.2	2.0	1.5	1.5	8.2
D2	60	1.5	1.0	0.8	-	12
SR-101	57-59	1	-	-	-	1.5
Global	56-58	0.7	0.3	0.3	-	14
x45CrMoV15	56-57	0.45	0.15	0.5	-	15

Key indicators:

- Overall average sharpness over 100 impact cycles;
- Number of impact cycles to turn the edge blunt at 500 BESS (resistance to permanent rolling);
- Sharpness by the end of the Phase II (elasto-plastic transition) – calculated as an average of 3 sharpness scores:
  after 40, 45 and 50 impact cycles.

Even without fancy graphs, just looking at the numbers, it is clear that edge retention correlates primarily with the content of wear-resistant alloys, then with the carbon content, and finally with the HRC.

However, when we look at the resistance to initial rolling in the first 5 impact cycles, we see that, though wear-resistant steels do withstand rolling by about 30% better, there is **no correlation between the wear resistance and resilience to initial rolling**.

KEY INDICATOR → **STEEL ↓**	**Average sharpness in the Phase I** (elastic deformation) average of sharpness scores in the first 5 impact cycles
Vanadis 10	243
CPM20CV or M390	231
Elmax	240
Lohmann PGK	313
D2	311
SR-101	285
Global	398
X45CrMoV15	329

The high-vanadium edge sharpness quickly moves beyond the shaving range to just sharp. Wear-resistant edges win in the long run, but in the first impacts a 10% vanadium edge apex rolls to the same extent as a 3%, and both the 3% and 10% vanadium edges lose their initial keenness

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almost at the same rate as a mainstream knife.
Higher wear-resistant blades win as stayers, but are equal sprinters.

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