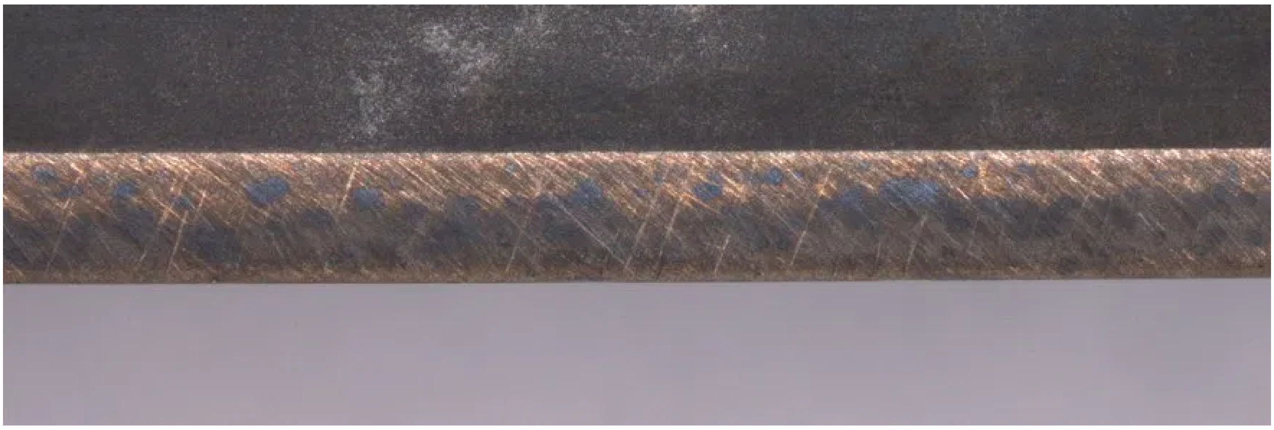
Knife Steel NERDS

MENU



CORROSION RESISTANCE, EDGE RETENTION, SHARPNESS

Does Acidic Food Affect Edge Retention?

January 21, 2019 Larrin

Thanks to Bill Wine for becoming a Knife Steel Nerds Patreon supporter!

I was interviewed on the Knife Junkie Podcast, so make sure you check that out.

Acidic Food

Carbon steel knives are frequently used in kitchens, probably the majority of them made by Japanese bladesmiths and knife companies. Kitchen knives cut a variety of foods, and some of them are corrosive. There has been some debate about whether any of these potentially-corrosive foods can actually affect sharpness or edge retention of kitchen knives. Sharpness is controlled by the radius/width of the edge. You can read more in the article on sharpness vs cutting ability.

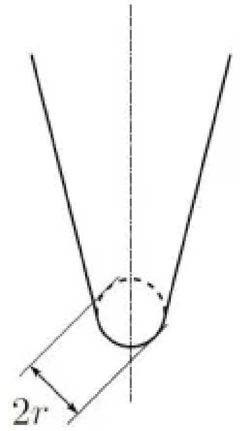


Figure 1: Edge diameter $2r$

This image from [1]

With typical wear of an edge during cutting the radius of the edge grows as the edge is worn:

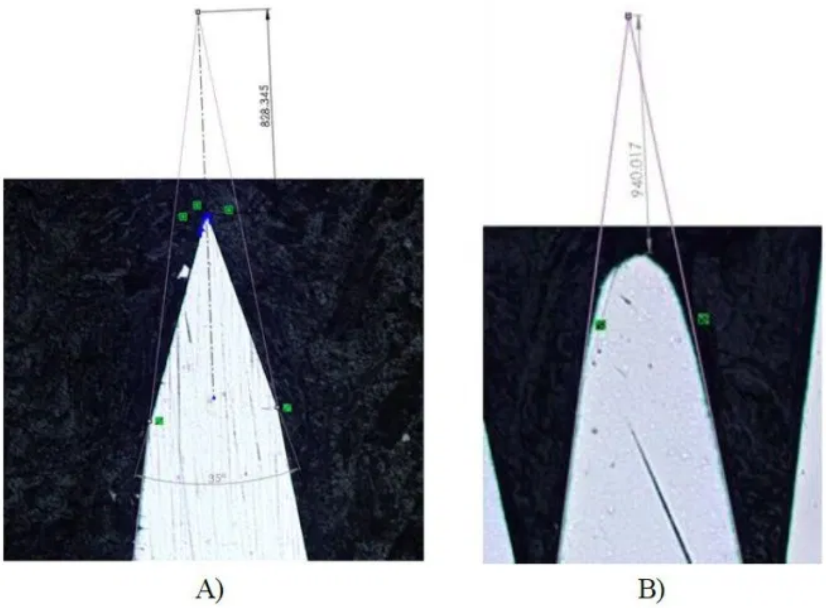


Figure 3-23 Measurement of depth of blade wear: A) New blade B) Used blade

This image from [2]

A very sharp edge has an edge width well under a micron, meaning that relatively little corrosion has to occur to potentially affect sharpness. We wouldn't necessarily expect the corrosion to lead to an increase in edge radius as with cutting. Perhaps the corrosion would lead to an increase in edge roughness, for example:

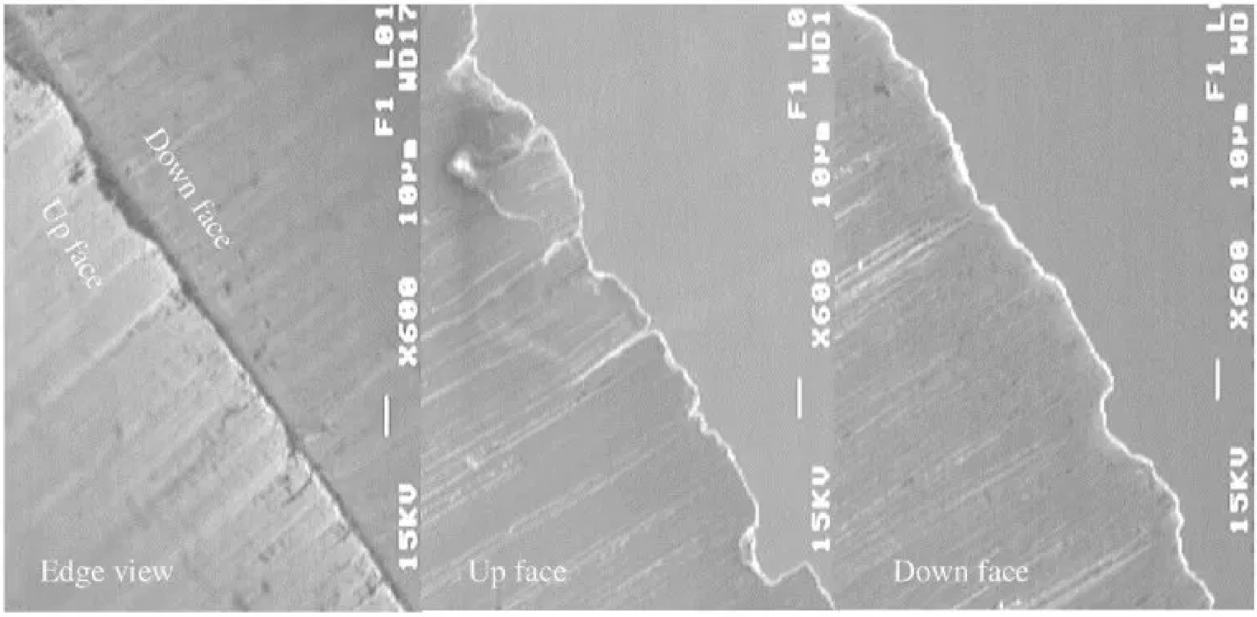


Figure 35 T edge of SS blade ground to 2Beta = 20° with Tormek SG-220 wheel

This image from [3]

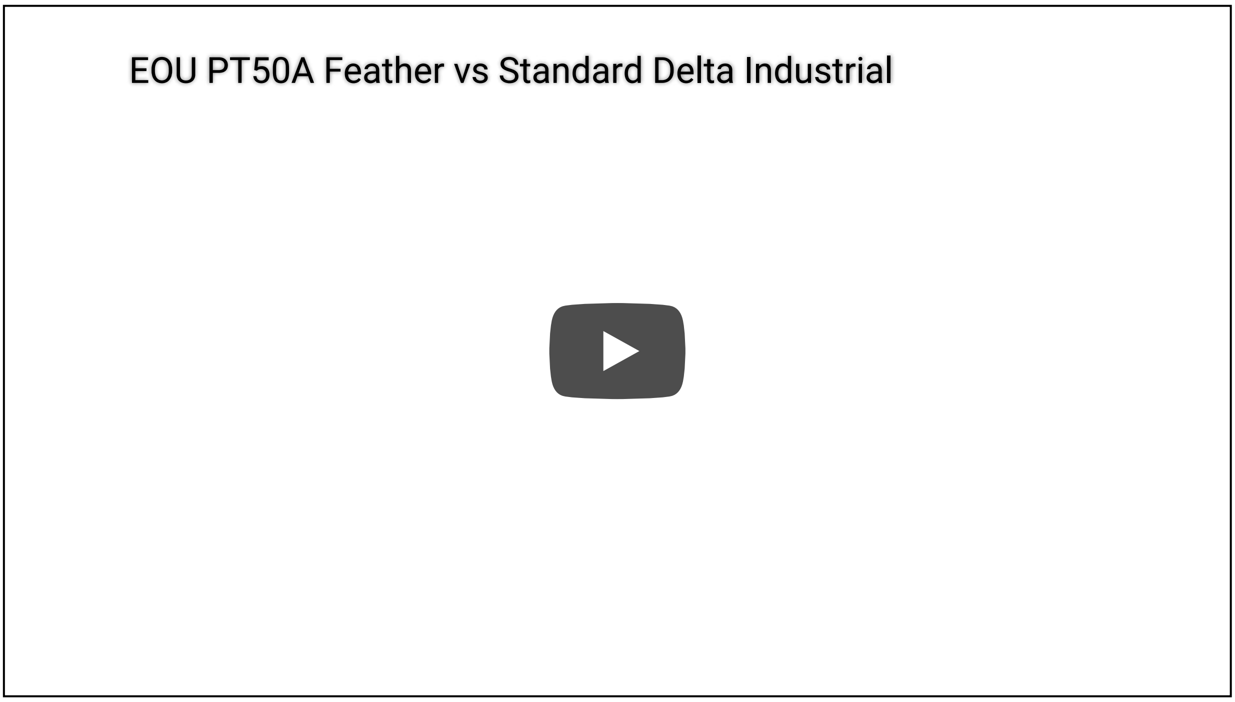
The Experiment

To look at the effect of corrosive foods on sharpness, I selected lemon juice as the corrosive agent. Lemons are one of the most acidic foods that a knife is likely to see, so it is a good worst case scenario to study. This allows us to see if loss in sharpness is actually possible at all. If no difference is measured in sharpness with carbon steel exposed to lemon juice, then corrosion of edges is not something to worry about. I decided to squeeze my own lemons, which means that the juice is likely more variable, but I didn't want any concerns about additives, etc. to the lemon juice that comes in a bottle at the store. I measured the pH of my fresh squeezed lemon juice at 2.6. It looked delicious so I tasted it and can confirm that it was unpleasantly sour.

I chose three inexpensive knives to compare the effect of corrosion, at three different levels of corrosion resistance. One is a knife in 1055 which is a simple carbon steel with no inherent corrosion resistance. Another is a D2 knife which represents a "semi-stainless" steel with moderate corrosion resistance. And a knife in 440A which is fully stainless and should have excellent corrosion resistance. The approximate chromium in solution for each steel is 0% for 1055, 6.5% for D2, and 13.9% for 440A. That chromium content in solution controls the degree of corrosion resistance of the steel. The method for estimating the chromium in solution is described in this article on corrosion resistance of knife steel. I re-beveled each of the knives to 20° per side using an Edge Pro with a diamond plate, and then sharpened it with a Sharpmaker, also to 20° per side. The 1055 knife is 53.6 Rc, the D2 knife is 62.0 Rc, and the 440A knife is 55.4 Rc. The low hardness and low wear resistance of the 1055 and 440A knives meant the re-beveling process was very fast, though it also meant the knives were difficult to de-burr.

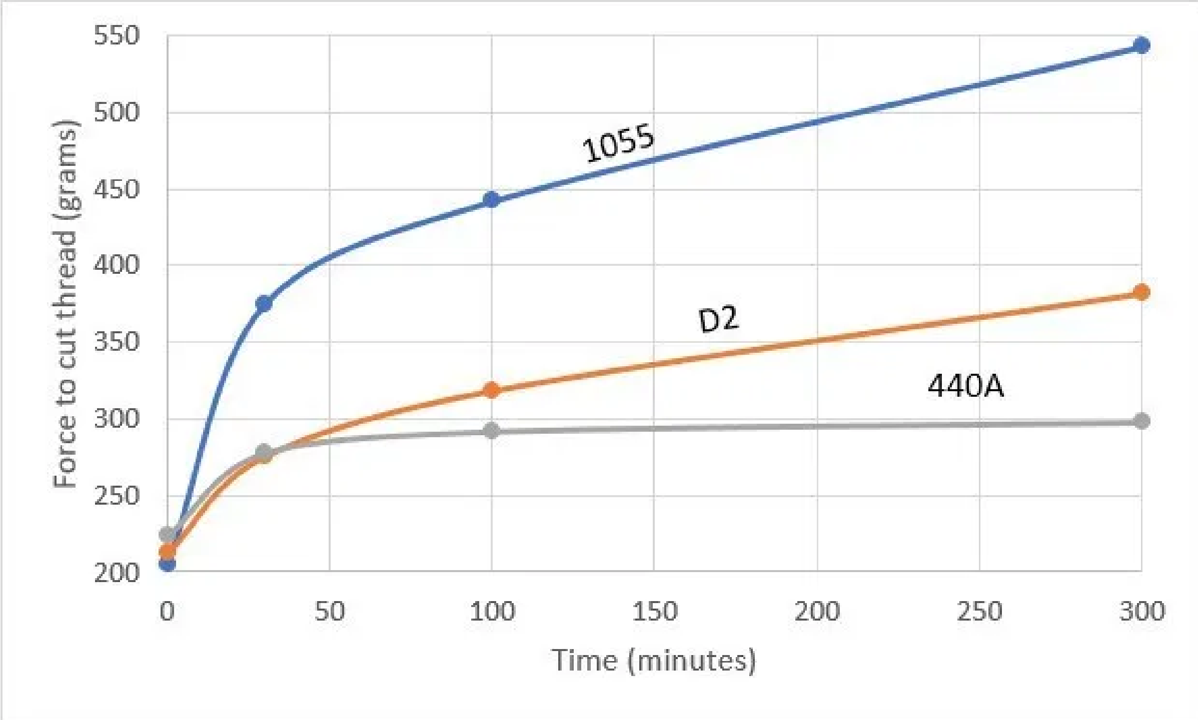
Results

I measured the sharpness of each knife with an Edge On Up sharpness tester using a thread made by BESS. The sharpness tester is a simple scale that measures the largest force applied while cutting the thread. Pushing straight down into the thread until the thread is cut measures the force required for a push cut. Here is a video put out by the company that demonstrates how it is used:

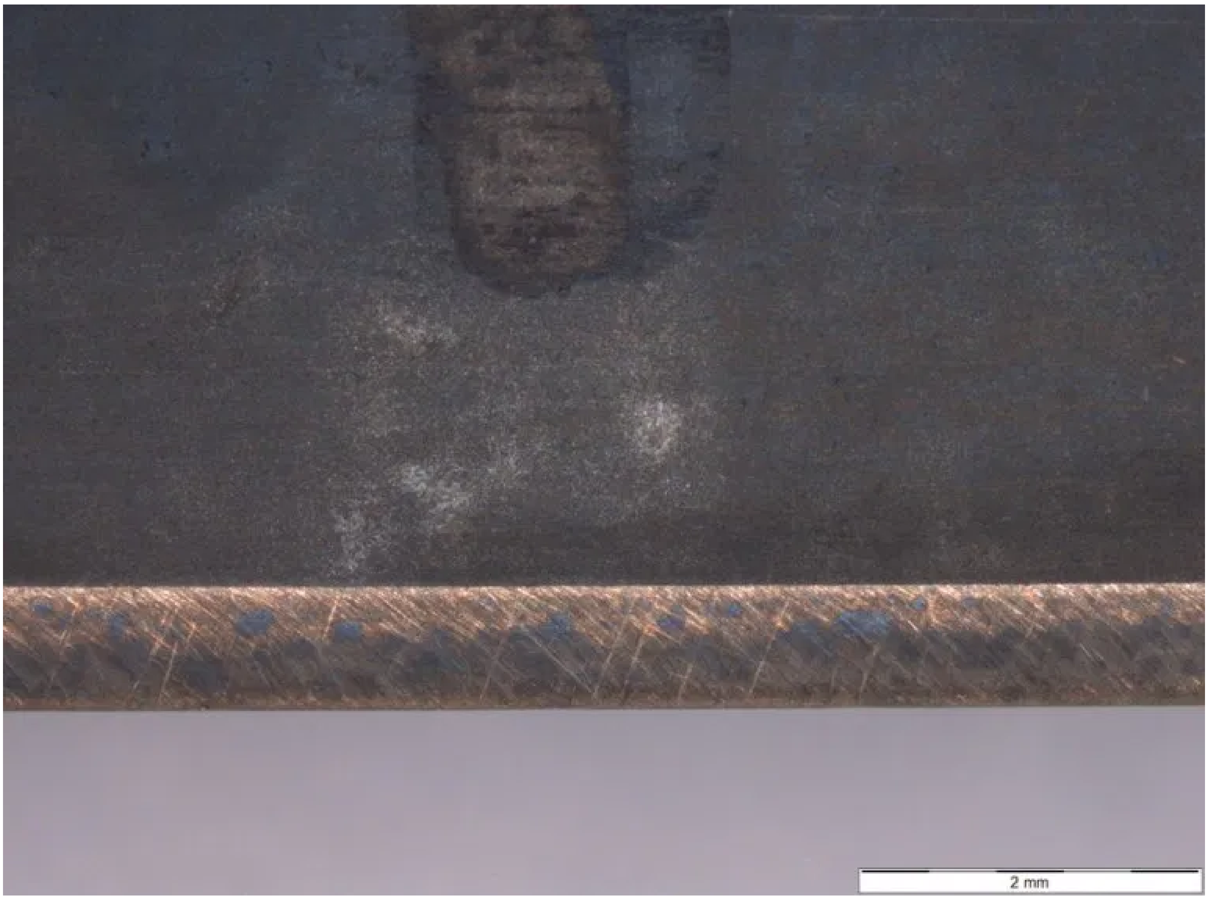


The freshly sharpened knives measured in the 200-220 gram range, which is moderate sharpness (more force means lower sharpness). A production knife from the factory is in the 230-300 gram range. A knife at very high sharpness would likely be more affected by corrosion as the edge width is very small. So being at moderate sharpness means this should be a relatively reasonable example.

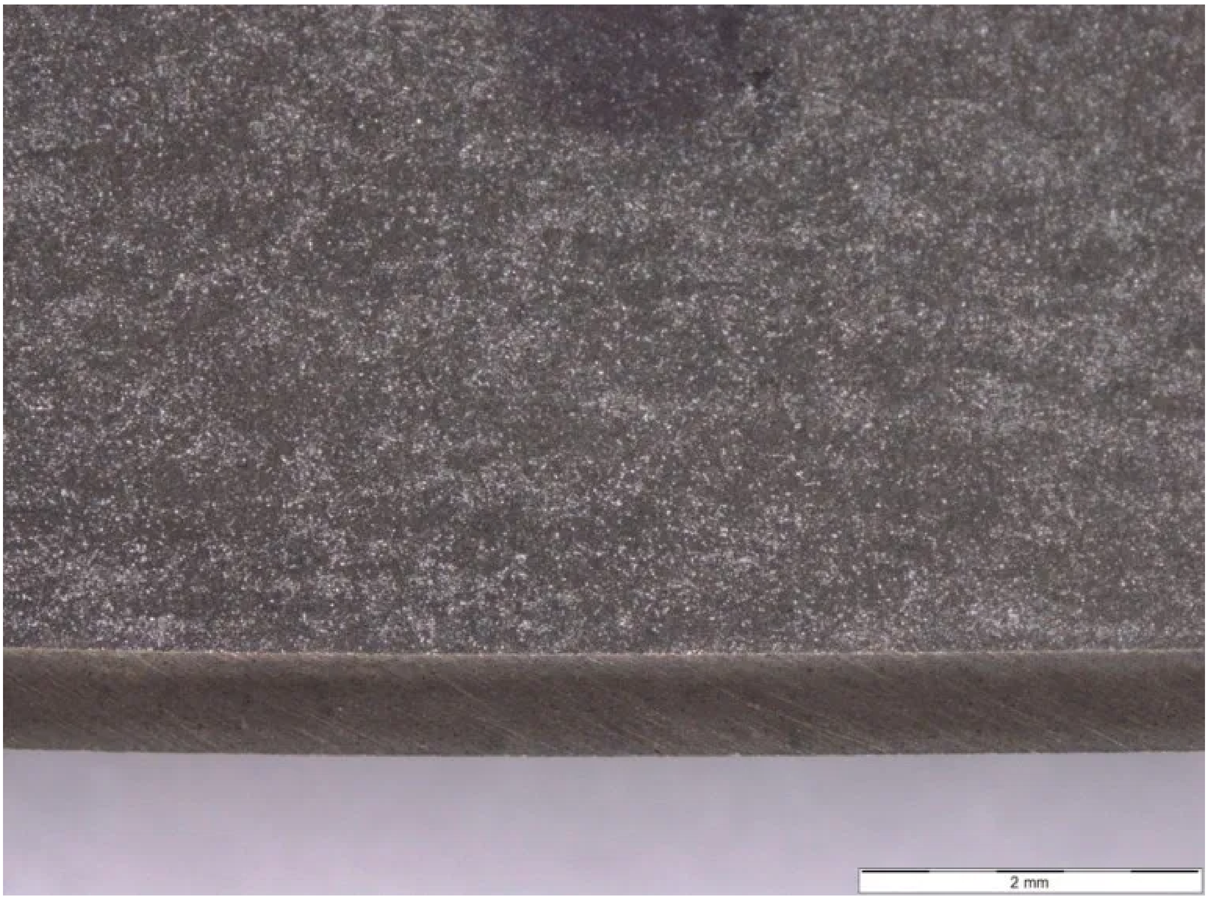
I dipped each knife into the lemon juice and then left it on my kitchen counter so that it is exposed to air while having the lemon juice on it. I cleaned the knife at 30 minutes and measured the sharpness of each, then dipped it in lemon juice again, and repeated at 100 and 300 total minutes. The 1055 knife reached the lowest level of sharpness, as expected. The 440A knife changed very little in sharpness. There was an initial loss in sharpness at 30 minutes and then it leveled off. The D2 knife was in the middle, demonstrating that full stainless is not required to prevent some edge corrosion.



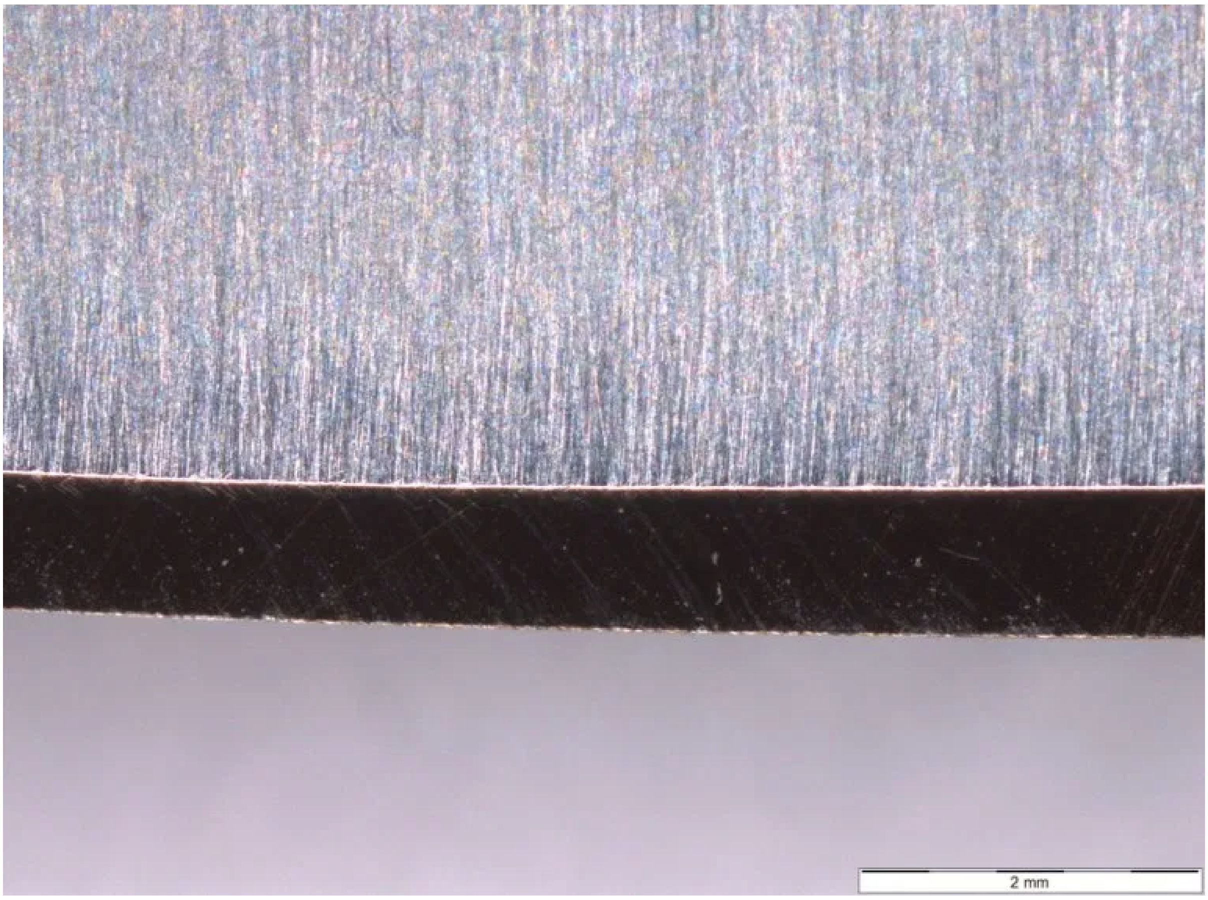
The D2 and 440A knives still sliced paper pretty well, though the 1055 knife was a little rough. I was surprised that the 1055 knife was still slicing paper okay, considering the relatively poor value it measured on the sharpness tester. I think that is because the edge corrosion is leading to increased edge roughness rather than increasing the edge radius. I don’t have sufficient magnification to compare before and after. That change in edge roughness greatly affected the push cutting sharpness test but was comparatively better at slicing paper. Looking at the 1055 and D2 edges, however, corrosion is evident. Surface finish is a strong controlling factor with corrosion, but since each knife was sharpened to the same level, the finish of the edges should be the same. The 440A edge was still so reflective I couldn’t even get a very good picture of it.



1055 knife edge after exposure to lemon juice



D2 knife edge after exposure to lemon juice



440A knife edge after exposure to lemon juice

Looking at the edges “edge on” also makes it apparent that the 1055 knife has lost more sharpness than the others. There are more “bright spots” in the edge, indicating that those areas are low in sharpness. In contrast, the 440A edge is largely not visible. The D2 edge is somewhere in between.

The corroded 1055 edge has many visible shiny spots

The D2 edge has a few barely visible regions

The 440A edge is difficult to see indicating better sharpness

Real Life

I don’t expect many people to spend 5 hours cutting lemons, though I suppose it is not impossible. Regular exposure to acidic foods is not out of the question, however, and the exposure is likely cumulative; the knife may be used and cleaned several times before re-sharpening. Lemons are not the only food that is acidic. Many fruits have a low reported pH [4]:

Food	pH
Lemons	2.0-2.6
Limes	2.0-2.8
Concord Grapes	2.8-3
Plums	2.8-4.3
Strawberries	3.0-3.9
Rhubarb	3.1-3.4
Pineapple	3.2-4
Raspberries	3.2-4.0
Apples	3.3-4.0
Peaches	3.3-4.1
Tangerines	3.3-4.5
Apricots	3.3-4.8
Oranges	3.7-4.3
Tomatoes	4.3-4.9

Cosmetic Changes

The 1055 knife developed a very obvious patina. The D2 knife discolored some but it is somewhat difficult to tell with the “black stonewashed” finish. The 440A wasn’t affected at all.

Conclusions and Future Tests

This round of testing was pretty successful. Extending it to more steels would be useful, both for confirming the validity of the test, and also for finding "cutoff points" where corrosion resistance is sufficient for acidic foods. It appears that loss of sharpness is possible with exposure to acidic foods, especially with simple carbon steel. "Semi-stainless" steels do have some corrosion resistance and therefore lose less sharpness than a carbon steel. I believe that the sharpness loss occurs through an increase in edge roughness rather than primarily through rounding of the edge like in slicing. Therefore, it is relatively easy to bring the sharpness back through something like a strop or a ceramic rod.

[1] http://www.hroarr.com/wp-content/uploads/2014/04/sharpness.pdf

[2] Adamovsky, Michael Francis Anthony. "The Effect of Cutting Blade Geometry and Material on Carbon Fiber Severing as Used in High-Volume Production of Composites." (2015).

[3] Verhoeven, J.D. "Experiments on Knife Sharpening." (2004).

[4] http://ucfoodsafety.ucdavis.edu/files/266402.pdf

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8 thoughts on "Does Acidic Food Affect Edge Retention?"

JASON STONE
January 21, 2019 at 8:25 pm

Interesting results. I wonder if some of the earlier reports of severe edge sharpness decline was from a small mirco-burr being left on from sharpening and then corroded off.

Reply →

DARSHANKUMAR DAVE
January 22, 2019 at 6:01 am

Hi Larrin,

That D2 blade may not be D2 (More likely it may be 8CR14MoV). Although looking at HRC data it may very well be D2.

My guess is based on PMI and HRC tests on an almost identical looking knife from Fura.

1. https://www.gearbest.com/pocket-knives-and-folding-knives/pp_1812055.html?wid=1433363
2.
https://docs.google.com/spreadsheets/d/1OepNr_D4lqbdTFqdqWl1rmAd4bOzPzJe6J0iEWrdJGU/edit#gid=0 Row 19

3. https://www.youtube.com/watch?v=cqsvN3XtYEQ

Reply →

LARRIN
January 22, 2019 at 7:58 am

Thanks for the info.

Reply →

MIKE THE SUPER INTERESTING PERSON
January 22, 2019 at 7:19 pm

I'm curious about your comment that a strop or honing rod could easily restore the sharpness of a corrosion-roughened edge, or at least more easily than if the loss of sharpness was due to edge rounding. I would have guessed that grinding past the edge pitting (if that's what it is) would remove an amount of steel comparable to what's needed to grind a new apex into a rounded edge. That's assuming the two kinds of loss in sharpness are comparable, and we can make an apples-to-apples comparison of the work required to remedy them. Hmmm.

Big thanks for all your work, this is super interesting stuff.

Reply →

LARRIN
January 22, 2019 at 8:57 pm

I wish I had a better method for comparing sharpenability.

Reply →

MIKE THE SUPER INTERESTING PERSON

January 22, 2019 at 11:13 pm

I think you may be right about the corroded edges being easier to restore than rounded edges with similar sharpness loss (again, if such a comparison can be made), if edge stability is taken into account as well as edge width.

I assume that the stresses that removed material from the rounded edges also weakened the steel left behind, and that this weakening goes deeper than the damage done (if any) by pitting to the steel bordering the voids? Or not. I'm just spitballing here.

Thanks again.

Reply →

PETER B.

February 17, 2019 at 4:36 am

Hello,

I have a super naive question:
Does hardness influence corrosion resistance (in non-stainless steels)?

Also, would a thinner edge be more suceptible to corrosion (lower edge angle)?

Reply →

LARRIN

February 17, 2019 at 8:48 am

Hardness doesn't directly influence corrosion resistance.

A thinner or more acute edge would have less material to corrode, so perhaps it would be more susceptible.

Reply →

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