The Measurement of Knife Sharpness and the Impact of Sharpening Technique on Edge Durability

Joshua Mulder & Jonathan Scott

School of Engineering, University of Waikato, Hamilton
jbm19@students.waikato.ac.nz, scottj@waikato.ac.nz

1. **Abstract**

We discuss the definition and measurement of knife sharpness. Using a commercial knife sharpness test system we identify a controlled cutting regime that progressively dulls blades, and use this to compare the durability of the edge on a modern knife sharpened with a commercial electrically-driven abrasive-belt knife sharpener with the same blade sharpened manually with a whetstone. Starting at similar sharpness levels we observe that the cold-sharpened edge is significantly more durable.

2. **Introduction**

Having a perfectly sharp blade is a luxury to some, but is an absolute necessity to others. In the food preparation industry for example, blade sharpness is of particular importance, where studies have shown that the use of substandard edges leads to operator injury over time due to increased force necessary [1] [2] [3] [4], while also greatly reducing productivity and producing inferior cuts [5]. There are numerous sharpeners on the market (and many videos on the likes of Youtube), all claiming to achieve the "ultimate" edge, but there are many professionals that still swear by manual stone methods of sharpening [6] as it is thought that powered, mechanical type sharpening overheats and thus detempers an edge. Such powered techniques, while initially giving a uniform sharp edge, are said to cause the blade to dull at a much faster rate through the same usage cycle due to the overheating of the edge during sharpening. The softer, detempered structure of the metal causes the edge to fold over more quickly and more easily, resulting in a dull blade [7]. We have found no reports of this in the professional literature. This may be attributed, at least partially, to disagreement on how to define and measure sharpness. We review the definition of sharpness, and choose a suitable measurement method. Next we investigate methods of challenging a blade to find a standard way of wearing an edge. Finally we will compare the durability of an edge achieved by powered and manual sharpening technique.

3. **Definition of "Sharpness"**

References [8], [4], and [9] all use the term "sharpness" to describe the performance of a blade, and [10] defines cutting ability as the property of a knife to separate a material that is weaker than the knife itself. The majority of researchers appear to fall into two main categories in their definition of what constitutes a sharp blade. References [4] and [9] for example, attempt to define sharpness as the force required to cut through a known substrate, while [8] introduces the idea that sharpness is best quantified by means of measuring the radius and edge angle of the cutting edge under a microscope. McCarthy et al [11] note that "to date, there is no standard definition, measurement or protocol to quantify blade sharpness". References [12] [8] [2], and [13] record similar findings, in that there is no single, widely accepted measure of just how sharp an edge is, nor method of testing different steels for their ability to take or hold an edge.

While there is yet no widely-accepted method of measuring sharpness, reference [14] attempts to implement one such standard. It concerns the sharpness and edge retention of knives for use in the preparation of food. The standard describes a test procedure to evaluate blade "performance" where the principle of the procedure is to mechanically reproduce a reciprocating cutting action by forward and reverse strokes against a synthetic test medium, under controlled parameters. The depth of cut produced in the material per cutting cycle is used to evaluate the blade performance. References [11] and [15] also attempt to create and use a new metric titled "Blade sharpness index" or "BSI" which incorporates much the same premise as previously used, where a method of quantifying the sharpness of a straight edge is derived from first principles and verified experimentally by carrying out cutting tests with different blade types and target materials. This is perhaps the most widelyadopted method of testing knife sharpness, wherein the load required to cut through a known substrate is measured.

Reference [10] notes that mechanical, force-to-cut analysis is much more sensitive to detecting wear than the geometrical (measuring edge radius/angle) approach. This has led to a wider adoption of this method, but it is not without its issues. Problems with the mechanical "force to cut" testing paradigm arise in that it usually requires that the blade is used for a significant amount of cutting [16] and this obviously leads to some degradation of the blade's cutting edge and consequently, also the variable being measured [11]. Additionally, this test evaluates sharpness by means of a qualitative test that involves cutting speeds, applied forces and test material that are difficult to consistently hold constant [16] [17] which can influence results significantly.

The Anago Knife Sharpness Testing machine (KST) provides the means for accurate, repeatable tests to be performed by substituting a proprietary, non-damaging test media while moving the knife through the material at a controlled, constant speed and angle [18]. Reference [4] details the overall development of this system. A "sharpness profile", or plot of force required to cut against position along the length of the blade, is produced during a test. This is produced in a repeatable and accurate manner. The Anago KST is pictured in Figure 1. The knife rides on a moving carriage and is advanced through a vertical strip of standard woven test media. A load cell is used to measure the force as the edge cuts each individual strand in the woven media. From this data a plot of sharpness along the length of the blade is produced.

Figure 1 - Anago Knife Sharpness Tester (KST)

4. **Method for Wearing the Edge of a Blade**

To be able to investigate the difference in edge longevity when comparing sharpening techniques, a standard method to wear or progressively blunt a blade is required. Three different methods were assessed for use as "cutting phantoms" where the ideal candidate would be able to slowly and controllably blunt an edge, simulating real world use.

The first method involved a piece of aluminium tubing where the edge of the blade was rolled over the surface of the metal as if trying to cut it, with a constant downward force applied to the top of the blade. A constant number of back-and-forth cycles of the blade over the tube, would constitute an equal amount of "work" done by the blade for each test. The aluminium proved much too soft in comparison to the material of the blade, with grooves being formed in the surface of the tube. We speculate that these grooves then served to support the edge after their initial formation, reducing the blunting effect of the aluminium. This can be seen in the resulting sharpness profiles (figure 3) where each line on the graph appears to virtually overlap with only minor variances, showing very little difference in sharpness between tests. It was the evident that this method did not have much effect on the sharpness of the edge and as such was not suitable for the purposes of further testing.

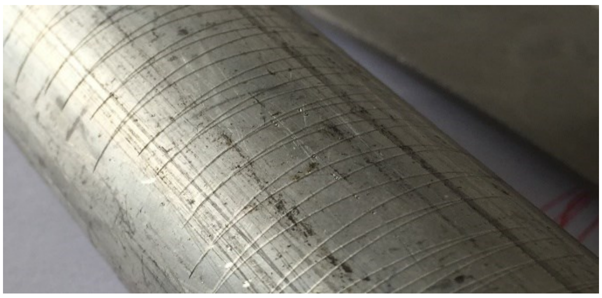

Figure 2 - Grooves formed in aluminium pipe diminish blunting capability

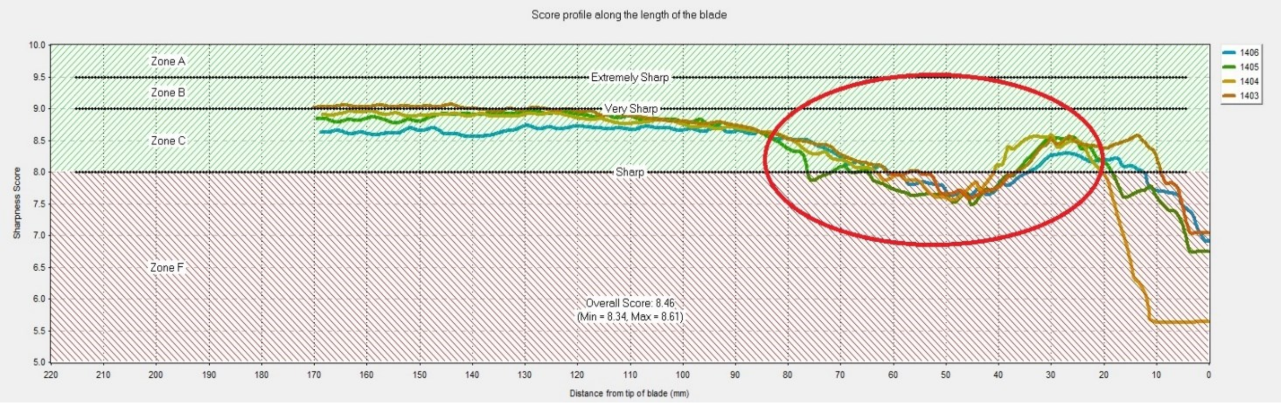

Figure 3 - Aluminium blunting test results. Area of interest (circled) shows no change is sharpness score between tests

Carbide emery paper was then tested for usefulness in simulating a real work load on the blade. This test followed the same principle as previous, where a set number of passes of the edge over the abrasive surface of the paper would constitute one unit of "work" done by the knife. It was quickly discovered that its abrasive properties were such that the edge was completely destroyed after only a few passes (figure 4). This result was at opposite ends of the spectrum from the aluminium tube test; where the aluminium didn't cause enough wear on the edge, the emery paper caused far too much wear too quickly. As such, this method was also disregarded.

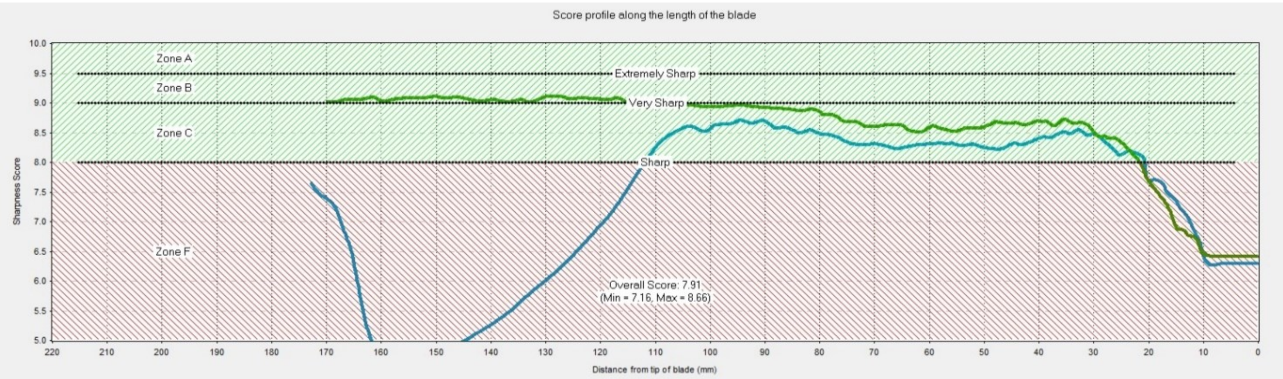

Figure 4 - Carbide emery paper results show edge is completely destroyed by only second test

The final method involved bamboo skewers. A single section of the blade was used to cut through a bundle of skewers. As shown in figure 6, a system was required that could exert considerable force to push the blade through the skewers. The results from the bamboo skewer were more promising. The data showed that the bamboo was successful in causing measurable wear on the blade, but this time in a much slower and more controllable. Figure 5 shows how the knife becomes progressively more dull through each test along the section of the blade used to cut through the skewers. This performance met our requirements exactly, and so this was the technique of choice for simulating blade wear in further testing.

Figure 5 - Bamboo blunting tests show gradual blunting of edge through section used for cutting (circled)

Figure 6 - Bamboo cutting technique with improvised blade tip holder allows more force to be applied while maintaining identical cutting motion between tests

5. **Sharpening Methods**

Two methods of sharpening were then explored with respect to their impact on the amount of cutting work the blade could handle before becoming dull. A Work Sharp Knife & Tool Sharpener (Figure 7) was employed as an example of a mechanical means of sharpening the blade which used an electric motor to drive an abrasive belt, against which the edge of the blade is held at a set angle with a blade guide. This tool had a number of interchangeable abrasive belts for rough grinding, up to a final polishing and gave a good consistent edge along the entire length of the blade and was found to indeed create a high amount of heat energy in the blade whilst in use. The second sharpening method tested employed a set of simple whetstones of varying grit. These stones were used with water as they would normally, which serves to keep the blade cool while also adding some lubrication to the edge. Though successful in sharpening the blade, this process did not give quite as uniform an edge as the electric tool in the absence of the skilled hand of a professional, but an acceptable edge was achieved for the purposes of this testing. These sharpening methods were then used, in conjunction with the bamboo skewer cutting phantom and Anago KST in further analysis where sets of thirty cuts were taken through the skewers in between sharpness tests. This allowed the gradual blunting of the edge to be seen with knives sharpened through both methods and a direct comparison between number of cuts and relative sharpness to be made.

Figure 7 - Work Sharp electric belt sharpener used for testing

6. **Edge Durability for Each Technique**

The stone-sharpened blade was tested first with measurements taken after 30, 60 and 90 cuts through the skewers. Figure 8 shows how the blade held up under the simulated work load. The sharpness score had dropped by 1.5 points from the initial sharpened score after 90 cuts at the point of interest. Tests with the belt sharpened blade (Figure 9) showed that the sharpness score this time dropped by about 2.5 points, and after only 60 cuts. This is a much larger drop in sharpness than with the stone sharpened edge which also occurred 30% quicker. The belt sharpened knife was only tested to 60 cuts since it had already become duller than the stone sharpened knife at 90 cuts. Also note how much smoother the lines are for the belt sharpened edge than the stone sharpened blade, indicating a much more uniform edge.

Figure 8 - Stone sharpened tests show a drop of 1.5 in the sharpness score after 90 cuts

Figure 9 - Belt sharpened results showing 2.5 point drop in sharpness score after 60 cuts

Since the blades did not score the same after initial sharpening, when comparing the two tests we must look at the score relative to the initial sharpness score for that blade and cannot make direct comparisons in overall score. Table 1 lays out all of the resulting scores and shows the difference between knives at each level of testing.

Table 1 - Resulting scores from tests of both knives with calculated difference between blades at each level of testing

cuts	stone		belt	
	score	drop	score	drop
0	8.5		9	
30	7.75	-0.75	6.9	-2.1
60	7.4	-1.1	6.5	-2.5
90	7	-1.5	-	-

We can see from these results that the belt sharpened knife dulled about twice as fast as the stone sharpened knife through both 30 and 60 cut tests. This is a significant result confirming that belt-sharpening a blade does greatly affect the longevity of the edge when compared to the performance of a stone-sharpened bade. This creates a trade-off between the ease of use of the belt sharpener which is capable of giving a highly sharp and uniform edge, and the skill level required to stone sharpen a blade well but which gives superior edge longevity.

7. **Conclusions**

Knife sharpness may not be a big deal to most people, but is vitally important to others. In the food preparation and meat processing industries especially, always having a sharp blade lessens the chance of operator injury, gives better cuts and keeps productivity up.
This study has found that the choice of method in how you sharpen your knives can play a big role in how long your edge stays sharp, which can potentially have a huge impact on time wasted sharpening and re-sharpening knives.
The results showed that using an electric, belt type sharpening device can cause a blade to dull two times faster than the same blade sharpened on a stone, although stone sharpening requires more skill to achieve the same levels of sharpness and uniformity along the edge.
If you can keep your blade sharper for longer not only do you spend less time sharpening, you

spend less time struggling to make cuts with a dull blade.

8. **Future Work**

Further testing could be done to explore how knives of varying quality and blade material are affected by this, as carbon content and harness of the steel the blade is made from may play a big role in determining how quickly the edge dulls in either situation. The difference between stamped and forged blades could also be looked at, but is not covered by the scope of this paper.

9. **Acknowledgements**

The authors would like to acknowledge Anago for their providing the KST testing equipment and analysis software.

10. **References**

[1] L. Claudon and J. Marsot, “Effect of knife sharpness on upper limb biomechanical stresses - a laboratory study,” *International Journal of Industrial Ergonomics,* vol. 36, pp. 239-246, 2006.

[2] R. L. Szabo, R. G. Radwin and C. J. Henderson, “The influence of knife sharpness on poultry processing operator exertions and the effectiveness of re-sharpening,” in *Proceedings of the Human Factors and Ergonomics Society*, 1998.

[3] D. Zhou and G. McMurray, “Modelling of blade sharpness and compression cut biomaterials,” *Robotica ,* no. 28, pp. 311-319, 2010.

[4] W. R. McGorry, P. C. Dowd and P. G. Dempsey, “A technique for field measurement of knife sharpness,” *Applied Ergonomics,* vol. 36, pp. 635-640, 2005.

[5] K. Newman, “Sharpening skills,” *Foodservice Equipment & Supplies Specialist,* no. 50, p. 51, 1997.

[6] B. Kramer, “Sharpening with Bob Kramer,” [Online]. Available: https://www.youtube.com/watch?v=kFhMGJYhYpU. [Accessed 10 January 2016].

[7] T. N. Ward, “Keeping on the cutting edge,” *House Beautiful,* no. 142.10, pp. 174-178, October 2000.

[8] G. A. Reilly, B. A. McCormack and D. Taylor, “Cutting sharpness measurement: a critical review,” *Journal of Materials Processing Technology,* vol. 153, pp. 261-267, 2004.

[9] J. Marsot, L. Claudon and M. JacQmin, “Assessment of knife sharpness by means of a cutting force measuring system,” *Applied Ergonmics,* vol. 38, pp. 83-89, 2007.

[10] S. Schuldt, A. J. Roschy, H. Rohm and Y. Schneider, “Defined abrasion procedures for cutting blades and comparative mechanical and geometrical wear characterisation,” *Wear,* vol. 300, pp. 38-43, 2013.

[11] C. T. McCarthy, M. Hussey and M. D. Gilchrist, “On the sharpness of straight edge blades in cutting soft solids: Part I - Indentation experiments,” *Engineering Fracture Mechanics,* vol. 74, pp. 2205-2224, 2007.

[12] S. Hainsworth, R. J. Delaney and G. N. Rutty, “How sharp is sharp? Towards quantification of the sharpness,” *International Journal of Legal Medicine,* vol. 122, pp. 281-291, 2008.

[13] J. Juranitch, The Razor Edge Book of Sharpening, Razor Edge Systems, Inc, 1985.

[14] ISO International Standard Materials and Articles in contact with foodstuff, “Cutlery and Holloware. part 5: Specification for sharpness and edge retention test of cutlery,” *ISO 8442-5:2005,* 2005.

[15] C. T. McCarthy, A. N. Annaidh and M. D. Gilchrist, “On the sharpness of straight edge blades in cutting soft solids: Part II - Analysis of blade geometry,” *Engineering Fracture Mechanics,* vol. 77, pp. 437-451, 2010.

[16] J. D. Verhoeven, A. H. Pendray and H. F. Clark, “Wear tests of steel knife blades,” *Wear,* vol. 265, pp. 1093-1099, 2008.

[17] K. H. Lau, D. Mei, C. Yeung and H. C. Man, “Wear characteristics and mechanisms of a thin edge cutting blade,” *Journal of Materials Processing Technology,* vol. 102, pp. 203-207, 2000.

[18] G. M. Hägg, K. Vogel, J. Karltun and R. W. McGorry, “How do different meat temperatures affect knife force?,” *The Ergonomics Open Joural,* vol. 8, pp. 27-31, 2015.

[19] Z. Yuan, M. Zhou and S. Dong, “Effect of diamond tool sharpness on minimum cutting thickness and cutting surface integrity in ultraprecision machining,” *Journal of Materials Processing Technology,* vol. 62, pp. 327-330, 1996.

[20] J. D. Verhoeven and H. F. Clark, “Carbon Diffusion Between the Layers in Modern Pattern-Welded Damascus Blades,” *Materials Characterisation,* vol. 41, pp. 183-191, 1998.

[21] R. W. McGorry, P. C. Dowd and P. G. Dempsey, “The effect of blade finish and blade edge angle on forces used in meat cutting operations,” *Applied Ergonomics,* vol. 36, pp. 71-77, 2005.

[22] R. W. McGorry, P. C. Dowd and P. G. Dempsey, “Cutting moments and grip forces in meat cutting operations and the effect of knife sharpness,” *Applied Ergonomics,* vol. 34, pp. 375-382, 2003.

[23] B. Kramer, “Carbon Steel - Youtube,” [Online]. Available: https://www.youtube.com/watch?v=RA5ExsqhHQI.

[24] M. A. Hayat and Y. Zhang, “Care and Use of Diamond Knives,” *Micron,* vol. 29, no. 5, pp. 411-414, 1998.

[25] T. Atkins, “Optimum blade configurations for the cutting of soft solids,” *Engineering Fracture Mechanics,* vol. 73, pp. 2523-2531, 2006.