2007 Study Update, Part 7

By

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Angle of Attack

The following angle of attack information is purely for those technically inclined. If you are not among those, you may want to skip over this first section and start at *Other Broadhead Testing*, on page 4.

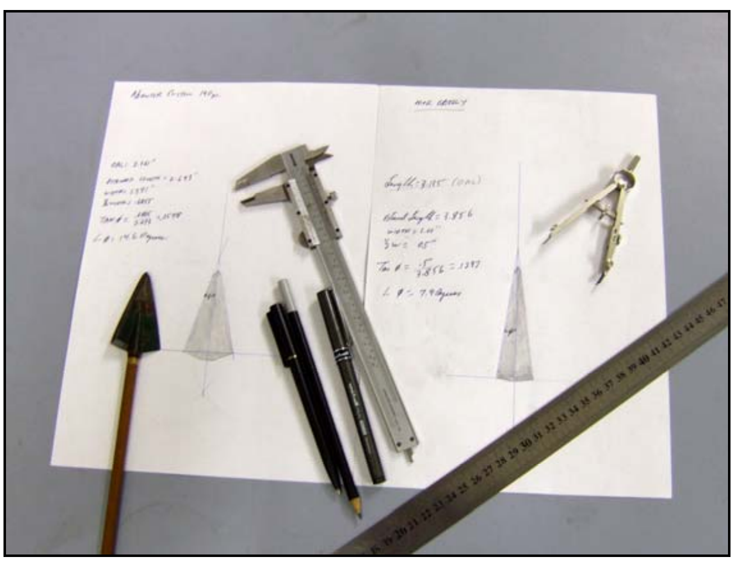
The angle of attack of a broadhead is the slope each cutting edge presents to the tissue as the broadhead penetrates. For a single-blade broadhead the attack angle equals one-half the total angle formed by the blade's edges. All else equal, the lower a blade's angle of attack the more effortlessly it passes through the tissues, conserving arrow force. It's precisely like a car driving uphill; the steeper the hill the harder the car has to work to get up it, and the more energy that's expended in doing so.

The angle of attack of a broadhead's tip can also be measured, and is a factor that appears to be of particular relevance during initial broadhead to bone contact and penetration.

An approximation of the angle of attack of a single- blade broadhead's cutting edges can be achieved by simply placing the broadhead on a protractor and measuring the angle subtended by the two blades, and then dividing the angle by two. However, the tip profile of many broadheads makes accurate protractor-estimation of the angle at which a broadhead's blades would meet a bit imprecise. Here's a simple-tool 'how to' for measuring the angle of attack for such broadheads more precisely, should you wish to do so. Absolute precision in determining angle of attack requires a computer assisted design (CAD) program.

When using the simple-tool method for concave or convex blades you still have to 'guesstimate' the 'average' angle of the blade in relation to the broadhead's center-line; center-ferrule to tip; using a protractor and straight-edge. For these broadheads it's best to just settle for that approximate measurement. For broadheads having straight-taper blades the simple-tool method is almost as accurate as a CAD program.

The first photo shows a couple of layout sheets; one for the 190 Abowyer and one for the Modified Grizzly. It's not necessary to shade in the broadhead's outline. That's been done to show the relationship of the broadhead to the layout lines. Note how both layouts extend somewhat below the horizontal line. This is necessary to get an accurate reading, and will vary with each broadhead's shape.



Layout sheets for a Modified Grizzly (R) and a 190 gr. Abowyer Custom (L)

Here's the method: Make a horizontal straight line. Using either a compass or protractor, construct a second line perpendicular to the first. Extend the perpendicular both above and below the horizontal line. Now take measurements of the broadhead, as closely as you can. Calipers and a good ruler will work; vernier calipers work better. The measurements you'll need are: (1) cut width at the blade's widest point; (2) overall Length (OAL) of the broadhead and; (3) any 'offset' measurements.

Offset measurements include such things as: (1) if the tip profile differs from the overall blade profile, how far back of the blade's tip does the tip profile end, and (2) how wide is the blade at that point (the rear tip-termination) and; (3) the distance from the back of the ferrule to the widest portion of the blade.

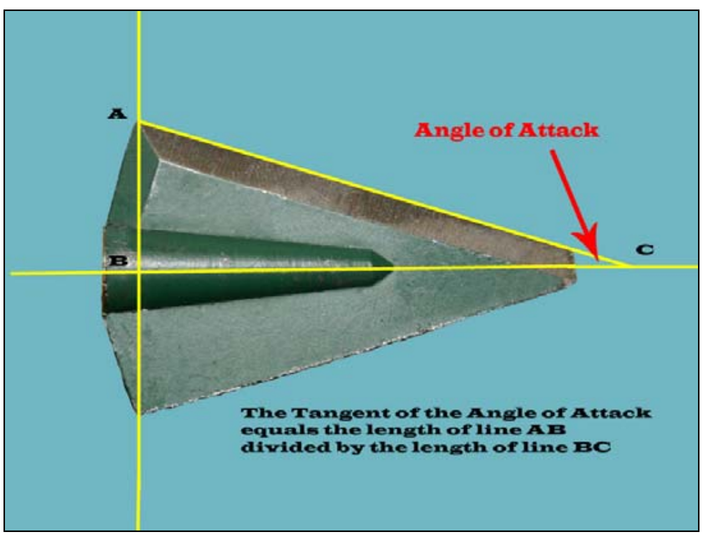
Armed with these measurements, you're ready to begin: (1) Lay out the broadhead's shape so that the widest point of the blade falls precisely on the horizontal layout line when the broadhead's ferrule and tip are precisely centered on the vertical layout line; (2) Mark the broadhead's width on the horizontal line. (3) Using your offset measurement, mark on the lower vertical line how far below the blade's greatest width the back end of the ferrule falls; (4) Using the OAL, mark the location of the broadhead's tip on the upper vertical layout-line; (5) Starting from the top OAL mark, mark both the location and width at the rearward termination of any tip-profile.

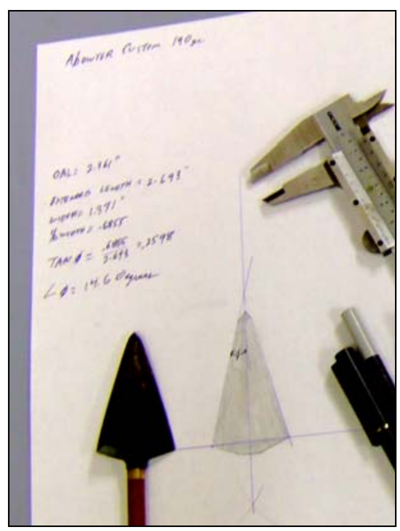
Using these reference points make a straight line, starting at the widest-blade-mark on one side of the horizontal layout line, passing through the tip-profile's width-mark (for that side of the broadhead) and terminating at the vertical layout line.

You have now constructed a right triangle. The angle formed at the top of this right triangle represents the angle of attack of the blade's cutting edge. At this point you can either: (1) measure the angle of attack with a compass; (2) measure the supplementary angle and subtract it from 180 degrees to derive the angle of attack or; (3) calculate the angle. If you have a vernier caliper to measure the length of the lines forming the angle, the calculation method gives a more accurate value. Any of the trigonometric functions can be used; sine, tangent, etcetera. Here's the method using the angle's tangent.

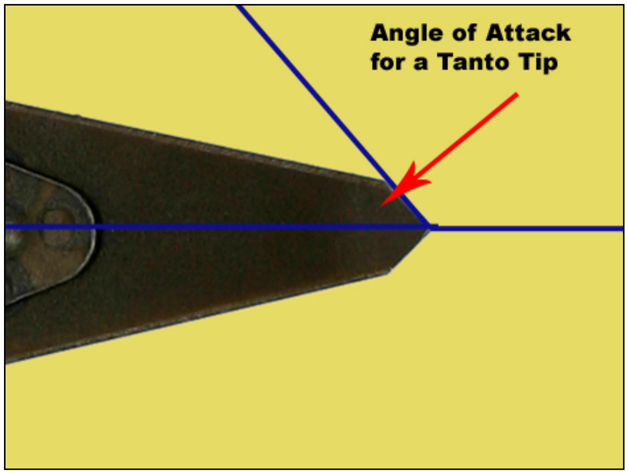
To calculate the angle of attack you'll first need to measure the "*Extended Length*" of the blade; the distance from the intersection of the horizontal and vertical layout-lines to the point where the line from the widest-cut mark intersects the vertical layout-line. The "*Extended Length*" compensates for any difference between the angle of attack of the tip and the blade's angle of attack. Now calculate the angle's tangent. Here's how.

To find the tangent of the angle of attack divide one-half of the blade's widest cut-width by the "*Extended Length*". For example, if the blade is 1.5" wide at its widest point, and the "extended length" is 3", divide 0.75 (half the cut width) by 3. The resulting number, 0.25, will be the tangent of the angle (which, in this example would be 14.05 degrees). The pertinent measurements and calculations can be seen in the following photos.





Angle of attack calculations for the 190 gr. Abowyer Custom.



Angle of Attack on a Tanto Tip.

The last step is to look up the 'tangent number' to see what angle it corresponds to. Don't have a table of tangents handy? That's no problem if you have a computer. Almost all computers come with a calculator feature including both standard and scientific calculators. Open the calculator. (In Windows, open "All Programs", select "Accessories" and click on "Calculator".) Once the calculator is open, go to "View" and select "Scientific".

Now simply enter a number representing an angle of however many degrees you think is close to correct, and then hit the key marked "tan". The number shown will be the tangent of the angle you have entered. If the number shown is larger than your calculated tangent number, then the angle you entered if greater than the blade's angle of attack. Try again, entering an angle containing a smaller number of degrees.

It takes very little bracketing with the scientific calculator to arrive at the correct measurement for the angle of attack; and you'll then know the angle at which the broadhead's cutting edge will engage the tissues as the arrow penetrates. This 'simple tool' process is not nearly as difficult to do as it is to describe. It is actually fairly fast and easy to use.

Now, let's take a look at the other broadhead test results.

Other Broadhead Testing

The R52 160 gr. Grizzly

In previous test bending problems were encountered with the 160 gr. Grizzly. Though having the same metal thickness as the 190 gr. Grizzly, the 160 gr. versions tested had a Rockwell hardness of R50 – exactly as the manufacturer specifies them to be – but the 190 gr. models have consistently tested a minimum of R52 hardness. Being somewhat shorter in length than the 190 gr. Grizzly, the 160 gr. version has a somewhat lower mechanical advantage (MA). This means that it would require more force to penetrate a given bone, and would also encounter a higher level of peak resistance force. The increases resistance force means greater stress on the broadhead.

Samples of the 160 gr. version, hardened to R52-R53, were supplied for retesting. Testing consisted of both broadside rib-impact shots and 45^0 adverse-angle shots into the scapula of a large buffalo bull. The broadheads were mounted on laminated birch shafts, having a favorable shaft-diameter to ferrule-diameter ratio and a total arrow mass of 815.5 grains. They impacted with 0.492 Slug-Feet/Second of momentum.

For broadside rib-impacts, average penetration was 14.31". On scapular shots, average penetration was 5.0". The higher Rockwell 160 grain Grizzlies came through all testing undamaged.

An interesting comparison is between these shots and the Internally Footed Extreme FOC arrows discussed in current Update, Part 3. All are from the same bow, on comparable animals. However, though they have 25.5 grains lower arrow mass the Extreme FOC's have the Modified Grizzly, of substantially higher MA. There is a 99%

difference in outcome-penetration for the scapula hits. Despite the Extreme FOC arrows encountering the limit of measurable-penetration, there is a 57.2% penetration-difference on the rib-hits. The difference results from Extreme FOC's greater 'useful force' being more efficiently applied by the higher MA Modified Grizzly; force *multiplied* by time of impulse.

Test shots taken with this harder version of the 160 gr. Grizzly substantially exceeds the number taken with the lower-hardness version. It appears that the level of hardness should be maintained at R52 or higher, making the 160 gr. Grizzly a more suitable broadhead for those pursuing truly heavy game animals; and a very good bone-performance broadhead for any bowhunter.

The Outback Supreme

This is a prototype Outback Supreme. It has a single-beveled, steel ferruled 0.073" thick blade hardened to R51. As tested, with Tanto tip modification, the weight is 209 grains. Testing was done with the 82# longbow, using Carbon double-shafts. Total arrow mass 880 grains, 11.1% FOC; impact momentum: 0.529 Slug-Feet/Second. For broadside rib-impact shots, on a large adult buffalo bull, average penetration was 16.29". All but one shot was low in the thorax. All except one imbedded into the off-side ribs.

On scapular impacts the Supreme showed a tendency to hang up in the scapular flat, with penetration tending to stop where the short ferrule fades into blade. None, however, suffered damage.

In earlier testing, the single-beveled aluminum-ferruled version of this head showed a penetration-range of 8" to 19", despite the fact that their testing was on smaller size animals. The most striking contrast is the steel-ferrule version's penetration-consistency. The aluminum-ferruled version showed a 22.9% damage rate, all of which was to the aluminum ferrule. Each occurrence resulted in low penetration.

The steel-ferruled Outback Supreme can be included in the 'best broadheads' list. It becomes only the second screw-mount broadhead to make the list; with the SilverFlame being the other. On rib impacts, it is well suited for heavy game. Currently, the steel-ferruled version is a special order item, but I am told they will soon become a production item.

Note: As I was re-proof this update (July 2008) Woody has informed me that his new machinery is just coming on-line, and we can expect much greater precision and consistency in the production Outback broadheads, as well as a much better edge finish. It's always great to see a manufacturer putting forth the expense and effort to provide us a better product.

Steel-Ferruled Outback Supreme

(Yes, the insert shown is 'loose'; the head was just stuck onto it for the photo)

The aluminum ferrule on this double-bevel Outback Supreme shows a deep gouge inflicted by a buffalo rib. A number of similarly damaged aluminum ferrules were recorded during their testing.

This is the shaft the aluminum ferruled Outback show above was mounted on. Note area of shaft finish removed by the bone. The arrow stopped in the rib. A broadhead's ability to relieve bone pressure against broadhead and shaft is an important penetration feature, as is *total* arrow integrity!

Magnus I (160 grain)

The Magnus I ('Delta' profile) was tested on both laminated birch shafts and double-shaft arrows. In earlier testing the needle tip showed a tendency to bend on some impacts, especially at oblique angles, but tip-modification halted these. For this retesting the tip was modified to a Tanto profile, and no tip damage was encountered.

The birch shafted arrows had a total mass of 790 grains, and impact force of .477 Slug-Feet/Second. Arrow FOC was 9.6%. Only one broadside rib-impact shot was taken. The penetration was 6.375", with the broadhead's tip barely making it through the rib. Two shoulder shots were taken. Both missed the scapula. Each showed penetration of 8.125, with both failing to penetrate the rib.

Three broadside rib-impact shots were taken with the broadhead mounted on a double shaft carbon arrow. Total arrow mass was 1054 grains. Arrow FOC was 13.8%. Impact Force: .577 Slug-Ft/Second. Average penetration was 12.754". Of the three shots, one resulted in a double lung hit; with one stopping in the on-side lung and one just touching the second lung. The Magnus I is a strong broadhead, but the wide width severely restricts its ability to penetrate bone. Its low MA (1.65) only slightly exceeds that of the 3-blade Wensel Woodsman (1.43). A look back at Chart 5, in the 2005 Update, Part 3, provides comparable penetration results for the Woodsman. On very similar arrows, the Magnus I out-penetrates the Woodsman by a modest amount. Both show difficulty in penetrating heavy bone.

The Magnus II (125 grain 'Standard')

As with the Magnus I, the tip on the Magnus II was modified to a Tanto profile for testing, and for the same reason. Testing was conducted on the same type shaft setups used for the Magnus I.

For the first series (laminated birch), total arrow mass averaged 743 grains; impact force was .475 slug ft/second and FOC was 6.3%. Only two broadside, rib-impact, shots were taken. Both hits were on the shoulder crease. One penetrated 11.25", giving a single lung hit. On the second shot a chip was broken from the blade, just rearward of the triple-thick tip overlay. The shot penetrated through the rib, with an outcome penetration of 7.125".

Magnus II with chipped blade.

Because of the location, at a juncture of single to triple-thick steel, it is *speculated* the main blade became a bit overheated during lamination, resulting in a spot of overly-hard, brittle steel. Such a failure is *greatly preferable* to having any degree of blade bending, as it shows far less penetration loss.

For the second series, the Magnus II was mounted on the double carbon shafts: Total mass was 1017 grains; impact force was .542 Slug Ft/Second; and FOC was 12.65%. Three broadside rib impact shots were taken. All reached the off side ribs, with two sticking firmly in the ribs. Average penetration was 18.67" (Range: 18.5" to 19.0").

The Magnus II has performed well throughout testing. However, as the earlier testing showed, the Magnus II's main blade occasionally bends on adverse-angle heavy bone impacts. Despite this, and the small blade chip, they have performed relatively well when the tip is modified and adverse impacts are avoided. As with the corresponding Zwickey broadhead, they are suitable for truly large animals when used on appropriate arrow setups, but the user needs to exert every effort to avoid adverse angle impacts on heavy bone with either.

The 125 gr. Ace Standard

This was the initial testing for the Ace Standard, and it was tested with the factory tip. Normally a series of 'punishment test' are conducted during all initial BH test, but the pre-planned retesting from previous broadhead test and the extensive punishment testing of the Internally Footed shafts used up all the available buffalo shoulder-areas this year. Because of that I do not have any heavy-bone/adverse angle test data for this broadhead.

Test series 1 was conducted with the heads mounted on tapered hickory shafts: Total Mass: 775 grains, Impact force .516 slug feet/second; 9.1% FOC. Four shots were taken. All shots were back of the shoulder, rib-only impact from broadside. None of the shots penetrated the rib. Average penetration was 5.5".

For test series 2 the 125 grain Ace Standard heads were mounted on the same double-carbon shafts used in testing the 125 grain Magnus II, presented above.

Total arrow mass was 1019.5 grains; impact force was .543 Slug-Feet/Second; arrow FOC was 12.7%.

Three shots were taken. All were back of the shoulder rib-only impacts, from broadside. On one of the shots the shaft broke, just rearward of the aluminum insert. The steel broadhead adaptor was also bent (a photos of that damage is shown in Part 2 of this year's Update series). This shot failed to penetrate the rib, giving 4.5" of penetration. The remaining two shots penetrated 14.875 and 15.25 inches, giving an average penetration for these two shots of 15.06", with both shots giving a modest second lung hit.

It is interesting to compare the penetration of the two non-damaged double-shafted arrow hits with the Ace standard to the results shown by the same shaft-setup when using the Magnus II. The test shots were taken on the same animal, with the Ace double-shaft series immediately following that of the Magnus II's double-shaft series.

Both broadheads have convex profiles, though the Ace is more convex than the Magnus II. As tested there is also a tip difference. The Magnus was modified to a COI Tanto profile tip, while the Ace was tested with the factory COI needle-tip profile. Both broadheads have near identical ferrule profile and fade-in, with the Ace having 0.334" greater blade length, giving it a somewhat better MA. Both broadheads have a triple thick tip overlay, with the tip thickness for the Ace being 0.063" and that of the Magnus II being 0.060". Main blade thickness is also similar: 0.030 for the Ace and 0.027" for the Magnus II.

Cut widths, as tested, measure near the same; 1.2 for the Magnus and 1.175 for the Ace. The shafts used are the same for both. Arrow mass varies by only 2.5 grains; with the Ace-tipped arrow being the heavier; a result of the Magnus II's Tanto tip modification. Impact force is near equal, with only a miniscule advantage to the Ace tipped arrow.

Considering the similarity of the two setups, casual observation would suggest near equal performance, with the slightly higher MA Ace showing somewhat more penetration than the Magnus II. However, that was not the case. Ignoring the Ace's one shot with structural failure, the Magnus II shows a penetration increase of 24% over that shown by the Ace Standard. The 'least penetrating' Magnus II shows 21.3% more penetration than achieved by the Ace Standard's best shot. Each shot with the double-shaft Magnus II reached to off-side ribs penetration-barrier. The actual penetration difference would be greater than 24%.

The photo of the two broadheads (below) shows a significant feature. It is the likely cause of this penetration difference. Note the smooth surface on the blade-face of the Magnus II and the five 'raised lugs' of ferrule attachments on each side of the Ace Standard.

The Ace Standard (L) and Magnus II. Note the abraded area just forward of one of the Ace's ferrule-lugs (arrow). These appeared several time on the Ace broadheads, and are areas where bone has gouged into the metal, as the lugs forced their way through the bone.

When you have a chance, run your fingers over the blade-face of these two broadheads, using very light finger pressure. Note how the Ace's raised lugs grabs at you fingers. That represents increased resistance. That's what it does in tissues, too.

Though it may *appear* there is little difference in these two broadheads, their dissimilarity is significant during tissue penetration. It's a classic example of how seemingly minor differences in design features can markedly influence penetration. Data contains scores of such illustrations. Attention to such minute penetration-degrading features of your arrow setup becomes increasingly important as draw-weight decreases and/or as the size of the game hunted increases.

The Ace Super Express

This massively-dimensioned 200 grain broadhead was tested on tapered hickory shafts, having a total mass of 848 grains; impact force was .519 Slug-Ft/Sec; FOC was 13%. Three shots were taken, from broadside. Two of the shots hit back of the shoulder, with rib-only impacts. Both failed to penetrate the ribs, giving 6.5" and 7" of penetration. One shot impacted on the shoulder, five inches forward of the shoulder crease. It missed all shoulder bones and stopped against the on-side rib; giving 11" of penetration.

This was all the rib-penetration the Ace Super Express could muster. The wide-cut and surface lugs attaching the ferrule cause high penetration-resistance.

The Cheetah

The right hand single-bevel version of the Cheetah was tested on double shaft aluminum/carbon arrows. Total mass was 932 grains; impact force: .541 Slug-Ft/Second; arrow FOC: 10.4%. Six shots were taken, from broadside. Two shots impacted on the scapula. These gave penetrations of 4.875" and 6.875", with neither penetrating the scapula. Four shots were taken back of the shoulder. All penetrated the on-side rib. Average penetration was 14.375", however they showed inconsistency. Two of the shots were thorax traversing; with the broadhead sticking in the off-side rib; giving 19.125" and 19.5" of penetration), but the other two shots yielded modest one-lung hits. Their penetrations were 8.75" and 10".

The Cheetah broadhead has an open-ring ferrule design. All testing of broadheads having this type ferrule indicate a high level of resistance during bone penetration. It is conjectured that a variance in the level of bone-resistance encountered by the open-ring ferrule, shot-to-shot, resulted in this disparity.

The Cheetah is one of the very few broadheads available in either right or left single-bevel, as well as a double-bevel version. The double-bevel version was tested in 2004, on the same shafting as used for this test. In that testing, for comparable shots (broadside, back of the shoulder with rib-only impact) the double-bevel Cheetah rendered a 50% failure rate of penetrating the entrance rib; and average penetration was only 7.9". Maximum penetration achieved by the double-bevel Cheetah on any of the broadside rib-impact hits was 12.25".

The substantially better outcome-penetration shown by the single-bevel Cheetah provides one more *demonstrative outcome* that, on bone-hits, a single-bevel broadhead has a decided penetration advantage over a double-bevel broadhead having, otherwise, the exact same dimensions and design. There is a 100% correlation of this outcome among all tests.

Some have suggested that an open-ring ferrule broadhead design chips away bone as it penetrates, opening a wider pathway for the trailing shaft and reducing shaft-drag. Testing does not support this contention.

The Cheetah is a very sturdy broadhead, and has quality steel. Only one has suffered damage in testing; a ferrule ring which cracked. Most notable, all the Cheetah broadheads have been tested with the factory needle-tip. It is the only *extensively-tested* needle-tip to come through testing undamaged.

The right single-bevel Cheetah's ring-ferrule design. Also shown is the factory-ground bevel angle.

In Part 8, the last in this Update Series, we'll look at a summary of penetration-enhancing factors, and how much each affects your hunting arrow's performance.