

Understanding Arrow Penetration

By J. L. Spinks

There is not doubt about it, this article is going to be controversial. I can already hear the screaming and gnashing of teeth. Still, it is based on fact and the laws of physics that are inviolable. Hopefully, those who read it will better understand how an arrow penetrates and make their own decisions regarding their equipment setup.

It's best to start at where we stand now. Almost everyone agrees that a heavy broadhead-tipped arrow will penetrate a live target better than a light arrow. Yet, bow manufacturers and arrow manufacturers continually advertise how "fast" their equipment is, normally with fairly light projectiles. They, and some very well-know bow hunters, point with pride to the "kinetic energy" generated by a fast arrow. They talk gleefully about how the velocity factor in the equation for kinetic energy is "squared", or multiplied times itself, to give a dramatic increase to the theoretical kinetic energy delivered by the arrow and broadhead combination.

Unfortunately, kinetic energy doesn't mean squat when it comes to predicting how well a projectile, including a broadhead-tipped arrow, will penetrate!

I know that statement raised a lot of eyebrows, but it is true. To demonstrate it, try shooting a 5 gallon bucket full of sand with a 230 grain full metal jacket .45 ACP round at 835 feet per second and also with a 550 grain broadhead-tipped arrow at 200 feet per second. The .45 bullet will not penetrate completely through the bucket while the arrow will. If the kinetic energy buffs were right, the .45 bullet with approximately 335 ft. Lbs. Of kinetic energy and 635 feet per second advantage in speed should penetrate far better than the arrow's measly 49 foot pounds of kinetic energy.

Why doesn't it? The answer is both simple and complex. Kinetic energy figures are great on paper, but in the real words, several other factors come into play. The friction of the medium, in the above example - sand, plays a tremendous role in how well a projectile will penetrate through that medium. Likewise, the momentum of the projectile and its shape as it passes through the medium are primary factors in determining how well the projectile will penetrate.

How does all this relate to kinetic energy and if kinetic energy is not an accurate measure for predicting penetration what is it good for? Kinetic energy is vitally important for understanding how high velocity projectiles, such as bullets, act when striking a living target. In these instances, the high forward velocity and high rotational speed of the bullet do impart tremendous energy to living, moisture-laden tissue. As a bullet impacts, it has what we will call an "impulse effect". It imparts some of that high forward velocity to the tissues it contacts, immediately accelerating those tissues to the same speed as the projectile. These high speed tissues then move along the paths of least resistance, creating tremendous temporary wound channels and dramatic shock effect to the animal that was struck by the bullet. Likewise, the rotational speed of the bullet also literally "throws" tissues away from the bullet, just like the spin cycle in a washer "throws" water from the wet clothes in the tub. All this together falls into the general explanation for hydrostatic shock.

Blunt and Judo point tipped arrows also work by producing shock in small game animals. As the head impacts an animal, the energy is transferred to the fluids in the tissues of the animal causing those fluids to accelerate to the velocity of the arrow. As with a bullet, those fluids then travel along the paths of least resistance throughout the animal's body causing shock throughout the animal's system. Depending on the size of the animal, the energy transfer and shock may or may not cause instantaneous death. Even in large animals such as deer, the energy transfer and shock can be enough to cause severe internal injuries and bleeding. That is why any bowhunter with a lick of common sense would not even think about "blunting" a big game animal.

As bowhunter, we all know that our arrows and broadheads kill big game animals by causing hemorrhaging, not by delivering a tremendous shock to the quarry. In order to cause that hemorrhaging, our broadheads must penetrate the animal's vital area, cutting through organs and severing arteries, veins and capillaries to cause both internal and external bleeding. That penetration is best determined by understanding the relationship between momentum (inertia) and resistance (friction). The reason our arrow penetrated the sand bucket in the previous example was that its forward momentum was enough to overcome the friction cause by the sand.

The momentum of an arrow is fairly easy to compute. It is based on the arrow's weight and its speed. Unlike like the formula for kinetic energy however, the speed factor is not squared, giving equal value to both weight and speed and helps explain why "heavy" arrows penetrate better than "light" arrows. The formula is fairly easy to use without being either a math whiz kid or a physics major. It is expressed as: $Momentum = Mass \times Velocity$.

The only tricky part of the equation, like that for kinetic energy, is determining mass. Rather than taking the weight of your arrow and multiplying it by the velocity, you must first take the weight in grains and divide by 7,000 to determine the weight in pounds. After determining the weight in pounds, you must then divide that result by 32 (for the force of gravity). The result from that equation is expressed in "slugs" and is then multiplied by the speed of the arrow to determine the momentum, expressed in "slug-feet per second."

Lets take a look at the arrow we used before to shoot through the sand to see how well it penetrates:

wt. = 550 gr.

Vel.= 200 fps.

For the equation:

mass = $550/7000 = .079$ lbs.

Then $.079/32 = .0025$ slug

finally

$.0025 \times 200 = 0.5$ slug/fps momentum

Now, what happens when we reduce arrow wt. By 190 grains to the AMO recommended minimum for a 60 pound bow, 360 grains, and gain 80 fps in speed?

Wt = 360

Vel = 280

mass = $360/7000 = .051$ lb.

Then $.051/32 = .0016$ slug

finally

$.0016 \times 280 = 0.448$ s/fps momentum

Now, given broadheads of identical design, cutting width and sharpness, the combination with .500 slug-feet per second momentum will penetrate better than the faster but lighter combination at .448 slug-feet per second.

If we had used the formula for kinetic energy, the lighter arrow would show a definite advantage at 62.7 foot pounds of kinetic energy versus the 49 foot pounds for the heavy arrow!

The one factor we do not have any hard data on in this equation is the resistance caused by the design of the broadhead. We do know that certain types of points penetrate easier than others. Broadheads with cutting tips slice through hide, muscle, sinew and organs with less resistance than those with pencil or pyramid points. Broadhead width and shape also are important factors to consider in determining penetration. A broadhead that is long in relation to its width would penetrate easier than one that is short and stubby.

The now generation of mechanical broadheads that open on impact also pose a dilemma for bowhunter. They may fly like field points but the resistance they encounter upon opening in a game animal is substantial. Consequently, they require significantly more momentum to achieve the same penetration as, say a Bear Razorhead.

What does all this mean to us bowhunters? Simply put, it explains why a heavy arrow/broadhead combination will penetrate better than a lighter one. In thin-skinned animals such as white-tails and mule deer the difference may be hardly noticeable. As the game goes up in size, the toughness of the hide increases, as do the size and density of the bones and muscles. The larger the game, the more momentum is necessary to penetrate the animal. The formula for momentum will give you a much better idea how well your arrow will penetrate than the one for kinetic energy.

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