2007 Study Update, Part 1

By

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The 2007 Update information is the most interesting to come from the Study, as it should be. Data is substantial and factor significance has clearer definition. Besides more on broadheads and other items of general interest, there's information about the three year effort to strengthen carbon shafts. The follow-on Extreme FOC information will be of special interest to those who hunt with lighter draw-weight bows. However, before we can launch into new findings there is prior information requiring attention.

Will it ever end?

It appears necessary to revisit kinetic energy and momentum. Why? Because some individuals have extracted one of the charts (Chart 4, *Summary: Extreme FOC's*; 2005 Update, Part 2.) and are misleadingly using it as an out-of-context example. For whatever reason, they have contrived highly invalid conclusions and widely circulated their false interpretation.

Ignoring textual content, the chart is being falsely presented as an 'example' that impact kinetic energy predicted the arrow penetration(s) shown in the chart. Additionally, it is being wrongly contended that Extreme FOC had no effect on the penetration outcomes shown.

This disingenuous non-contextual use deleted all frame(s) of reference, excluding both comparative results and all relational information. Edification is required. Minor false impressions can be ignored, but correct understanding of arrow *force* is vital to comprehending the factors affecting tissue-penetration.

The Chart's purpose

The sole purpose of Chart 4 was: *(1) to present cumulative data for all Extreme FOC arrows tested to date; (2) illustrate suggestive data that the heavy bone threshold is persistent for Extreme FOC arrows and; (3) show that performance of Extreme FOC arrows tested had reached the measurable-penetration limit; requiring lower impact-force testing before the penetration-effect of Extreme FOC could be accurately quantified.*

Chart 4 is not a comparison of Extreme FOC arrows against that of their matched-sets. That information is in the (advantageously omitted) accompanying text. The bogus conclusions being circulated can only be made to appear plausible by excluding comparative data.

Confused and/or adding confusion

The chart's accompanying text makes it difficult to understand how anyone could have read it and reached the conclusions being disseminated. It is *only* through ignoring the text's 'equal-dimension, equal-impact' test information, and the effect created by both the *penetration-barrier* and the *measurable-penetration-limit* (delineated in Updates) that anyone could misinterpret the chart as indicating arrow FOC has no affect on penetration, or that impact kinetic energy predicted the penetration outcomes.

Penetration barriers and the limit of measurable penetration

Arrows reaching off-side ribs with insufficient retained force to breach the bone are halted by this formidable barrier, limiting outcome penetration. Additionally, maximum-measurable penetration is confined by the span of tissue penetrated. To show the pronounced effect of the penetration-barrier and measurable-penetration limit; let's reiterate the matched-set information, from the omitted text.

The omitted 'apples to apples' comparisons

The accompanying text's three (expediently omitted) test series each comprise arrow-sets having equal external arrow dimensions; shafts, broadheads, mass, impact force *and* impact kinetic energy. They vary only in FOC. First, let's examine the high-mass Extreme FOC comparative results; Set 1 in the omitted text.

These Extreme FOC arrows show a 19% penetration gain over their matched-group. The gain would be much higher except for two factors: (1) the dimensionally-matched set of normal FOC high-mass arrows also produced high penetration, routinely reaching the off-side ribs, and (2) for the Study's purpose, "penetration" is defined as the depth of the wound channel through tissues.

For broadside thorax hits on adult bull buffalo, reaching the off-side ribs represents 16" to 19" of penetration; depending on hit location. The maximum measurable-penetration on any comparable hit is limited to between 19" and 25"; again, depending on hit location.

Because of penetration-barrier and measurable-limit effects, the greatest penetration-increase any *individual* high-mass Extreme FOC shot could possibly show is around 35%; even if it passed completely through. These constraints not only limit an individual shot's penetration, it restricts the average for all shots.

It is likely that, about here, someone will ask, "Why not measure penetration on the shaft?" The reason is simple. Study data is not for buffalo alone. On smaller animals there are often pass-through shots. How do you accurately measure total penetration when an arrow passes completely through? You can't. The only static measurable-feature remaining is the length of the wound channel. Both exit-wounds and pass-through shots are noted as adjunct information.

The lighter Extreme FOC arrows in (omitted) Series 2 & 3 far out-penetrated their dimensionally and kinetically equal normal-FOC comparison groups; by 58% and 62%, respectively. Those sizable increases are *despite* the fact that the Extreme FOC arrows hit the penetration-barrier and limit of measurable-penetration.

If, as incorrectly concluded by those isolating the chart, kinetic energy was the predictor of penetration and Extreme FOC had no affect, why do the Extreme FOC arrows uniformly show enormous penetration-gain over their identically-matched sets of kinetic energy equal normal FOC arrows?

The conclusion that the near-equal penetrations shown resulted from the near-equal impact kinetic energy, and that FOC had no bearing on the outcome, conveniently disregards these matching-set results. Were all directly-comparable tests merely overlooked; or were they advantageously omitted to make the false conclusion appear plausible?

The incongruous parallelism

Impact kinetic energy shown by the Extreme FOC arrows in Chart 4 falls within a narrow range; 33.78 to 40.49 foot-pounds. This is to be expected, since the same bow was used for all testing. Arrow mass varied from 620 to 985 grains, resulting in greater variance of impact momentum.

Measured penetrations for the Extreme FOC arrows in this chart are indeed very uniform. This, however, is emphatically not a result of kinetic energy parallelism.

Outcome penetration is uniform because: (1) The chart reflects *only* the Extreme FOC arrows; (2) 92.3% of these reached the off-side ribs; (3) 44% of those penetrated beyond the rib and; (4) 25% of those exceeded the limit of measurable-penetration. Among the 39 shots, only three Extreme FOC arrows failed to reach the off-side ribs.

To demonstrate how the penetration-barrier and measurable-limit dominated penetration outcomes: Ignoring the Chart's four shots in the lowest-mass test set (those below the heavy bone threshold), average penetration for the remaining 35 shots is 20.38" … and the *Standard Deviation* is a mere 0.825". Incredible consistency, to say the least! (Graph 2, also handily omitted, illustrates the penetration and measurable-limit effect.)

At the impact-force (momentum) level used, the Extreme FOC arrows encountered both the off-side penetration-barrier and the measurable-penetration limit. For over 92 percent of these shots, measurable-penetration was *required* to fall somewhere between these two measurement-confining features. The average measurable penetration had no option other than to be near equal.

Penetration exceeding accurate measurement made quantifying Extreme FOC effects impossible. This was one reason the chart was presented; to show precisely why a new series of lower impact-force Extreme FOC test was required. That data will be presented in the 2007 Updates. It more accurately quantifies Extreme FOC's gain in terminal performance.

Other oversights

Also not mentioned as the chart was non-contextually presented is the fact that the impact kinetic energy level of all arrows shown in Chart 4 falls *far* below that recommended by kinetic energy proponents as minimum for buffalo-class animals. Additionally absent is any mention of the Study's numerous attempts to find any *predictive correlation* between impact kinetic energy and outcome tissue penetration. Data presented for the highest kinetic energy group of arrows tested to date was totally ignored, so let's look at the specifics.

More 'apples to apples'

The highest impact kinetic energy testing employed arrows of 381 to 450 grains mass (average mass: 417.62 gr.), having favorable shaft-diameter to ferrule-diameter ratios and normal to high levels of FOC. All shots included in the following are back-of-the-shoulder rib-only impacts, from 20 yards; equivalent shots to those in Chart 4. These high kinetic energy impact shots were also on a large adult buffalo; fully comparable to those used in the Extreme FOC test shown in Chart 4.

Average impact kinetic energy for these shots was 82.99 ft. lbs. (Range: 76.64 to 94.12 ft. lbs.). Average momentum was 0.556 Slug-Ft/Sec. Average penetration was 12.20".

There are thirteen shots in this group. Two (15.4%) of the high-kinetic-energy-impact arrows reached the off-side rib … but four (30.8%) failed to penetrate the entrance-rib. Compare these normal FOC, extremely high kinetic energy impact results with those of Chart 4's Extreme FOC arrows. The Extreme FOC arrows average only 46.3% as much impact kinetic energy, but average 67% more penetration. Did impact kinetic energy predict the outcomes? Is an Extreme FOC effect *indicated*?

To provide further relativity, let's also look at some other comparable shots to that highest kinetic energy impact group. Let's examine higher-mass, lower impact kinetic energy arrows … from a longbow. The following shots are on equally large buffalo. They all have the same back-of-shoulder shot placement, shooting angle, shooting distance, broadheads, favorable shaft-ferrule ratios, and normal to high FOC. We'll also exclude all extreme high-mass 'specialty' arrows; the double-shafts and high-mass hardwoods (ipe and purple-heart). Those arrows are 'non-typical', and inclusion further prejudices results in favor of the slow-heavy arrow.

Average arrow-mass for the longbow group is 783.47 grains. Average penetration was 13.92". This is 14.1% more penetration than achieved by the highest impact kinetic energy group. The higher-mass arrows accomplished this with 35.32 ft. lbs. of kinetic energy (average); only 42.6% as much as the highest kinetic energy impact group. Average impact-momentum was 0.496 Slug-Ft/Sec; 9.8% less than the highest kinetic energy impact group.

With given impact-force and resistance, the greater contribution mass makes to arrow momentum the longer it takes the arrow to stop. The result is a longer *time of impulse*. Did impact kinetic energy predict the outcomes between the longbow's like-arrows and those of the highest impact kinetic energy group? Do results *suggest* arrow-mass' contribution to momentum influenced the outcomes?

Perhaps erroneous interpretation of the chart occurred merely because some folks did not take time to actually read the Update. Perhaps they also did not read the preceding ones, and stopped reading before reaching Part 5; where kinetic energy and momentum findings reflecting cumulative-data were presented. Whatever the reason(s), it appears necessary to reiterate how these factors relate to an arrow's tissue penetration; as dictated by the Laws of Physics and *consistently verified* in the real-tissue outcomes.

In real tissues, outcome-data manifestly exhibits …

While impact momentum cannot be used as a stand-alone predictor of penetration it does show *positive correlation* with outcome penetration; it demonstrates *relevancy*. This means impact momentum can be used as a *predictive function* when all other arrow penetration factors are constant.

With a constant arrow, real tissue data confirms: Average tissue penetration increase is *directly proportional* to the increase in *impact momentum.* Several instances of this have been presented in Updates, and yet another will be showing up in the new Updates.

Among actual outcomes, kinetic energy has failed to show positive correlation with tissue penetration. It is <u>not</u> useful as *either* predictor or predictive function.

On casual observation it might appear that kinetic energy should be applicable. After all, a substantial portion of it is represented by the arrow's velocity, and arrow velocity is a contributive component to momentum. However, any direct kinetic energy application overlooks important factors: (1) the disproportional increase in penetration-resistance *actually exhibited* by tissues as velocity increases; (2) the mechanics of the *impulse of force* during penetration and; (3) the fact that, by its very definition, kinetic energy cannot be used as either a measure or indicator of *force*.

It is due to disproportional resistance increase and impulse mechanics that the penetration/kinetic-energy relationship *steadfastly* exhibits *decrement* during tissue testing. The penetration-increase to kinetic-energy-increase ratio is not proportional.

Decrement should not be confused with a negative correlation. It simply indicates that the *rate* of penetration-increase constantly decreases as impact kinetic energy increases. With a constant arrow, the percentage of penetration *gain* becomes smaller each time impact kinetic energy is increased by a set amount.

So, one more time …

With a given structurally secure arrow having perfect flight: On any hit, outcome penetration depends upon the *impulse of force*. The impulse of force quantifies the transfer of arrow force (momentum) to the tissues with respect to time. It represents the net-force applied *multiplied* by how long the force acts upon the tissue(s); which also equals the change in arrow momentum. Impulse has the same units of measurement as momentum.

Energy is not a measurement unit of *force*, and cannot be used as such; period. Kinetic energy indicates the (total) *energy* a body derives from motion; nothing more. Arrow momentum is derived from a *portion* of the kinetic energy and the arrow's mass. At the instant of impact, arrow momentum represents the *total potential force* delivered at the target. It is applicable because it *defines* the arrow's directional force. A *force* must have both amount and direction of action. *Energy* has an amount, but no direction. These are textbook particulars.

Kinetic energy is merely a physical quantity describing the activity state of matter. Momentum is within an object in motion; a *property* of the object. As such, it is carried with the object. Force occurs between objects. Impulse reflects how an object in motion gives up (transfers) its force (momentum).

For example

An over-simplified but easier way to understand kinetic energy, momentum, force, work, and impulse is to think of the money you have in the bank, the money you earn, and how each is used up.

The money in your bank account is there; you already have it. It's your starting balance.

For the work you do, you earn additional money. Some of what you earn is squandered, and some you save.

Once deposited, the saved-money combines with what's already in your bank account. Together they make up the total bank balance. All of the bank balance is at your disposal.

When you spend your savings, you use up a portion of that bank balance, but you also get something in return; a 'work benefit'. Though not necessarily something useful or practical, anything you spend your savings on represents a 'work benefit'.

Kinetic energy is like the money you earn. It's what you receive for the 'work' of drawing your bow. Some of those 'earnings' will be squandered (the kinetic energy that does not contribute to the arrow's momentum), and some (the part contributing to arrow momentum) will be deposited into your 'bank account'. Once deposited, that useable kinetic energy becomes part of the 'bank balance'.

What you already had in the bank (the arrow's mass) plus the contribution (the usable kinetic energy) makes up the total account balance (the arrow's momentum). This represents the total potential force at your arrow's disposal as it impacts the target.

Force is what happens when you spend some (or all) of the account's balance (the momentum) to buy a 'work benefit'.

A large part of the 'work benefit' your hunting arrow 'buys' with the momentum it spends will be tissue penetration; a 'necessary and useful' purchase.

However, not all of the 'work benefits' your arrow purchases with its momentum will be 'necessary or useful'. Non-useful expenditures are represented by such things as overcoming shaft drag, having to overcome a poor shaft-diameter to ferrule-diameter ratio, or pushing a low mechanical advantage broadhead along. It also includes force expended whenever an arrow is deflected, or the shaft, broadhead, insert or adaptor bends or breaks.

The ***impulse of force*** reflects the average rate at which your arrow 'spends' its momentum, and how long it stays on its 'spending spree'.

The analogy is: the average amount of money you spend each day multiplied by the number of days you spend it equals the total amount spent during that period. It tells you how much of your bank balance you've used up. Subtract that from your starting balance and you'll know how much of your balance remains.

When an arrow stops within an animal, the entirety of the 'starting balance' has been expended, and your 'new balance' is zero. If the arrow passes through, you still had some 'balance' left in your account at the time of arrow exit.

In both bank-balance examples there are two inescapable facts: (1) whether you spend it fast or slowly, the bigger your account's starting balance the more you can purchase; and (2) regardless of how big your account is, the more frugal your spending habits, the longer your account's starting balance will last!

These two facts also dictate the only ways our arrow's penetration can be increased. We can apply more force, or make better use of the force available. Unfortunately, there is a limit to how much force we can achieve with a bow; and it's a paltry amount. Because of our arrow's low mass, we can achieve only about 10% as much *force* as a hand thrown spear. Making your arrow more miserly with the force it carries offers the best opportunity for improvement.

Efficient arrow design conserves momentum, expending it more slowly, resulting in a longer *time* of impulse. Since the *impulse of force* is momentum multiplied by time, the net gain from making your arrow more efficient is *truly* greater than the sum of the parts; it's the product of them! On any shot that isn't a pass-through it's a win-win situation; more retained momentum acting for a greater period of time … and each *multiplying* the effect of the other.

Real tissue data supporting the applicability of momentum and impulse of force as the appropriate penetration-indicator of an arrow is substantial. I would like to believe the issue can be put to rest, but I doubt that will be the case.

Regardless of all pontifications, every look at the Study data has returned the same bottom line for the momentum vs. kinetic energy issue: For shots into real tissues, momentum has *demonstrated* a predictive correlation with the actual outcome penetration. Kinetic energy has *persistently failed* to show that correlation.

In these newest Updates you will find several points to ponder between kinetic energy, momentum and impulse of force emphasized. Hopefully it won't be necessary to point out the differences in future Updates.

It is unfortunate some folks can't seem to get beyond the kinetic energy vs. momentum issue. Obtaining maximum terminal performance from your hunting arrow also depends heavily upon quality of arrow flight and a host of arrow-design features. There are many things you can do to make your hunting arrow so stingy with the *force* it carries that it would bring tears of envy to a Scotsman's eyes! *Arrow momentum is merely one among many penetration factors. The Study's goal is to locate, define and quantify them all.*