

Understanding and Applying FOC

By

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The 2005 Study update, Part 2, related the status of Extreme FOC testing, and set study FOC definitions. In its aftermath many questions have been received. There is significant interest in FOC; and much confusion. What is FOC; what does it do; how much FOC is needed; how and why does it affect tissue penetration; and what measuring method is "most correct"? Questions received are too numerous to answer individually. The following is presented in hopes it answers most.

What Does FOC stand for? It is an abbreviation for "Forward of Center"; but is commonly use as total replacement for the phrase "weight forward of center".

What does weight forward of center mean? The common answer is: FOC represents how far forward the arrow's balance point is from the shaft's midpoint ... or the mid-point of the arrow's total length; and we will discuss that "definition difference" later. FOC is specified as a ratio of balance point to shaft's (or arrow's) mid-point; in percentage.

For *practical purposes*; uses archers commonly apply FOC to; the definition(s) above is sufficiently correct. However, should one wish to be precise: *FOC represents the percent a projectile's gravitational balance point is forward of the projectile's center of pressure (CP)*. The CP is that point where the maximum "bending force" is exerted upon the projectile. The CP is dynamic for an object in flight; changing as propulsion forces, resistance forces and forces exerted by moving air currents change. For convenience, our "practical purpose" formula(s) merely assumes the CP to be at the mid-point.

Is precise FOC measurement critical to flight characteristics? Well, yes; if trying to calculate a trajectory to guide a missile to hit a pinpoint target from 2000 miles away! For archers; no, precise measurement is not critical. All we require is a *relative reference point*.

Why do we need a FOC reference point? What does it do for arrow flight? Think of FOC as indicating the arrow's fulcrum point. The further forward it is, the longer the "fulcrum arm", or "lever", of the fletching. [Note that this represents the "rearward lever".] The longer this lever, the more pressure a given amount of fletching can exert upon the arrow, increasing its control (degree of stabilizing effect). Having higher FOC makes the

fletching's job easier. If wishing to alter FOC, having a *reference point* tells us "where we are"; "which direction we are going"; and "how much change" we've made.

How much FOC does one need? The range of FOC recommended for different forms of archery varies. In their charts, Easton shows the following recommended FOC ranges, with calculations based on the AMO Standard formula:

- o FITA (Olympic Style) 11% to 16%
- o 3-D Archery 6% to 12%
- o Field Archery 10% to 15%
- o Hunting 10% to 15%

FITA shooters, who compete at the longest ranges, use the highest average FOC's; 3-D shooters the lowest; with field archers and hunters in-between.

Why do FITA shooters prefer a high amount of FOC? They are seeking precision long range accuracy. To achieve this, the arrows must be very stable in flight. High FOC permits stabilization from relative smaller fletching. Smaller fletching offers a lower drag factor and is less subject to the effects of cross-winds than larger fletching. These factors become important at the extreme ranges at which FITA shooters compete.

What is the lowest FOC usable? It is possible to use arrows with slight amounts of negative FOC; and some flight shooters use these. This works whenever drag force is sufficient to prevent the arrow swapping-ends in flight. Most flight shooters lean towards use of neutral to very low FOC. They feel low FOC flight arrows maintain a "nose up" attitude longer, providing longer flight. Some recent flight records, set using relatively high FOC arrows, are challenging this concept.

Hunters need fairly high FOC. Broadheads exert a steering effect upon the arrow, due to wind-shear. Fletching must overcome these "wind-plane" forces. High FOC means fletching has a longer "lever", and more steering control.

The shorter the arrow one shoots, the higher the FOC should be. Shorter arrows are inherently less stable in flight. The longer rear lever helps fletching overcome this. A finger release also adds to arrow instability, especially in initial flight. Here to, high FOC is beneficial.

How does one "correctly measure" FOC? The AMO Standard uses shaft-length; ignoring insert/tip/broadhead length. The other common formula uses overall arrow length; including

insert/tip/broadhead. Which is "correct"? Neither. True FOC is based on the center of pressure. We simulate the CP location in both formulas.

The AMO formula was adopted as "standard" because; of the two common formulas; it uses a "simulation point" nearer the actual CP location for *most* arrows in flight. Note the CP does not reflect the point of greatest shaft flex, but that upon which "flexional force" is greatest. Shaft design and material has a significant effect on both CP location and where the shaft will flex most.

For *practical* applications; those for which archers use FOC; either common formula works equally well. All that matters is that the method used be stated; so everyone "reads off the same page" when making comparisons. As with static spine, in-and-of-themselves the "numbers" mean little. They allow *relative* comparison of one arrow to another; nothing more.

For example, static spine measures *relative stiffness* of a shaft; how much it flexes when a weight of *specified* mass is suspended mid-way between two shaft-supporting points; which are located a *specified* distance apart. Everything about the measurement is *relative*, not *absolute*.

Static spine tells nothing of an arrow's dynamic spine. From it one gleans only an *indication* of *relative stiffness*. What it does do is provide a *reference point*. This helps when one needs to move to a stiffer or softer spine. It allows comparison of shafts; *relative to each other*.

This is why tuning arrow to bow is important. No static measurement or calculation contends with the myriad variables encountered when one shoots an arrow from a bow. That's why, besides charts, Easton publishes 35 instructional pages on attaining "the right arrow". Charts provide no magic number saying; "Pick me. I'm the right one!"

FOC measurement is the same; *relative*. Neither common formula is "correct", nor is either "wrong". Each serves its purpose; providing a reference point. As long as one knows which was applied, they can duplicate results. If preferred, then re-measure and state it in another format; that's perfectly alright. It still provides "relative reference".

If FOC indicates fletching's "lever arm" and resultant stabilizing effect, what led to its inclusion as a tissue penetration factor? FOC measurement has been around in archery a long time, but shaft materials limited the FOC achievable *with good arrow flight*. Carbon shafting has

created an abundance of possibilities. They behave differently. "Old rules" may not be applicable. Carbon shafts offer great stiffness at low mass, with forgiving flexional characteristics. I've found no shafting, other than carbon, giving good flight at Extreme FOC. Carbon shafts allow unprecedented FOC with exceptional flight.

Many hunting with Extreme FOC arrows reported conspicuous penetration increases. Subsequently, they were included in the study. Testing confirmed the reports. Extreme FOC arrows give *significantly* greater tissue penetration, when all else is equal. The frequency and magnitude of test results is too consistent and extensive for one to conclude otherwise.

Why does Extreme FOC give more tissue penetration? They encounter lower resistance. The reduced resistance results from less shaft-flex on impact. Prior testing has shown shaft flex increases shaft-drag, and shaft-drag is a major influencing factor on penetration.

How and why do Extreme FOC arrows achieve this reduction in shaft flex? Reduced shaft flex is *related* to CP location, relative to the arrow's center of mass. Extreme FOC means the *predominate* arrow mass has a very short lever arm. The shorter this lever arm, the less the flexion when obliquely acting force is applied at the arrow's tip. It is *suspected* that, for a given shaft, the effect *may* be *proportional* to the ratio of the lever arms; when all else is equal. *Should this prove true*, one would want as high a FOC as possible when maximizing penetration.

Extreme FOC arrows have at least two design features which reduce shaft flex on impact. These are:

1. Less arrow mass is towards the rear, reducing the force with which the arrow's rear "pushes" on the shaft.

This is easier to understand if one thinks of super-gluing a brick to one end of a slender shaft. Now place the other end of the shaft on the floor. Unless one keeps the shaft absolutely perpendicular to the floor, the shaft flexes.

Next, bump the shaft against the floor. Even when perpendicular, the shaft flexes at impact. Collision forces are *required* to go somewhere. The resultant force vector; between floor-impact and "push" from the rear; must either compress the shaft linearly, or be redirected, causing shaft-flex.

Now reverse the shaft, placing the brick on the floor. The shaft does not flex. Bump it up and down. Shaft flex is

scarcely visible. This is a drastic example of this Extreme FOC effect, but clearly demonstrates what happens.

2. Extreme FOC arrows concentrate arrow mass far forward. The *forward* lever arm is short. This means the *dynamic* center of pressure at impact is also far forward.

To understand how this short lever with forward mass affects shaft-flex, think of the distance from arrow front to balance point as being a short section of shaft. The shorter the section, the stiffer it is. The stiffer it is, the less it flexes.

Here one may wish to use the slender shaft and brick again. Hold the shaft near mid-point and turn it such that the shaft is not vertical. Note the "bending". Without changing the angle at which the shaft is held, shorten the "forward lever" by holding closer to the brick. The shaft flexes less. The closer one's hand is to the brick, the less the brick's "given force" flexes the shaft.

It is hoped the forgoing will help clarify FOC, how it is used, and its many effects. For those interested, here's the AMO Standard Formula again:

(1) Measure shaft length; bottom of thenock's throat to the most rearward portion of the broadhead taper.

(2) With tip mounted, determine the balance point by balancing the arrow on a knife edge. Mark this balance point.

(3) Measure balance point distance; from the bottom of the knock's throat to the balance point.

(4) Divide balance point distance by shaft length. This gives the decimal equivalent of the balance point's percentage relative to shaft length.

(5) From this quotient subtract 0.50, the decimal equivalent of 50%.

(6) Convert the resultant decimal fraction to percent by multiplying by 100 (or simply moving the decimal point two places to the right). This gives the percent FOC.

In formula format one has:

$$\%FOC = \left(\frac{\text{Dist. knock throat to Balance Point}}{\text{Shaft Length}} \right) \text{ minus } 0.50 \times 100$$

If one wishes to use the alternate method, merely substitute total arrow length for shaft length. The answer will be different; but the arrow will still be the same! If wishing to compare the FOC of one's arrows to those in *Arrow Lethality Study Update - 2005, Part II*, one should use the AMO Standard formula.

As is the case with most arrow design factors, the measurement methods we all use are nothing more than "numbers". They are relative values having little real meaning other than when comparing one arrow to another. It's all part of the language of archery. Just so long as one knows which definition from 'archery's dictionary' is being used, all works well!