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The Mechanics of Arrow Flight 101

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Thunk! The arrow you just released from your bow has hit its target. Or has it? Due to a number of factors, your arrow may or may not have landed where you expected it to. Some of these factors we have control of, some of them we do not. In addition to our form and technique, bow weight, string size, shaft weight, arrow length, vanes or feathers are all things we can at some point control. Wind, air density, and obstacles are factors we cannot control. We certainly can't ask a deer to just wait a minute for the wind to drop.

Unlike a bullet which is the same for each shooter and can be used in many different guns, an arrow has unique properties that are singular to each archer. The characteristics of which are determined by bow weight, draw length and perhaps some personal preferences. The purpose of this article is to explain what happens during an arrow's flight from bow to target, especially the critical milliseconds as the arrow leaves the bow.

Initially, the bow is just a means to an end. From the point the arrow leaves the bow it has nothing more to do with the task at hand, which is, the arrow finding its target. The scant amount of time the arrow is in contact with the bow i.e. from release to clearance is critical and will be analyzed by archers until the end of time. By removing the human factor and looking solely at the arrows flight we can gain some understanding of this somewhat obscure aspect of archery.

It seems so simple. Put the arrow on the bow, aim and shoot. But why then is there so much talk about equipment? What's the best bow? Who make the best broadhead? Should I switch to a different type of arrow rest? I'll tell you why. Because its fun. We all have a drive to learn and the more we learn the more we crave. It's a vicious cycle.

Perhaps I should start by offering a little background of myself. I've been around archery for as long as I can remember. When I was a boy I'd go shooting with my dad who was a member and co-founder of the 3M archery club. As I got older and Flex-Fletch Products was just beginning, I helped fill orders in our home office by hand counting and packaging vanes. My dad was always traditional when it came to archery and never used a sight or release aid. His one concession was the compound bow. He preferred to shoot instinctively and since he was my dad and I looked up to him I decided that was the style for me.

Archers Paradox Effect

By definition a paradox is a statement or situation which seems contradictory. An example of a paradoxical statement would be: "A penny saved is a penny earned". Whereas in reality a penny saved is a penny not spent.

The term "Archer's Paradox" was coined by Dr. Robert P. Elmer, a well-known archery author in the 1930s. He used high speed film to analyze the behavior of an arrow upon release.

In this case the paradox in "The Archers Paradox" lies in the fact that when using a traditional finger release, an archer must compensate for this effect by not really aiming at the spot he/she wants to hit. Due to the forces placed on the string from the fingers release the string is essentially flung leftwards, (assuming a right handed shooter). Perhaps this is not a true paradox, but close enough.

For the purposes of this article all references to the shooter hereafter will assume a right handed shooter, standard 3 finger release.

The forces on an arrow

So let's follow an arrow as it travels its path from the bow to the target with stops along the way to analyze what is happening during each particular instant. We will be taking the path of least language. In other words this isn't going to be a technical journal but more of a common sense approach to the actions and reactions of an arrow in flight and some of the variables in between. Lets face it we don't need all of the formulas to understand that if you drop a rubber ball onto a flat hard surface it's going to bounce. While the forces on an arrow in flight are much more extreme than this, by breaking it down we will be able to better understand the physical forces present during this event.

We prepare our two items the bow and the arrow, by putting the nock end of the arrow on the string at the prepared nock point. Proper nocking points are made of tread mixed with a drop of glue or ready made metallic nocking points which you just press with pliers on the string. Proper placement of the nock on the string is critical to arrow flight. Some say the arrow should be level and some say the nock should be slightly high. Usually a little trial and error is called for.

We begin to draw the bow string back until the bow is at full draw. Our arrow is secured to the string via the nock. The energy stored in the bow is now quite significant and we want to be sure we hit our target. Now... the fingers relax on the string, and of course, the arrow is released. Here's where things get very interesting. The moment the string is released incredible forces take over and place the arrow under a great amount of strain. In a very small amount of time the arrow goes through quite a lot. Being that the shooter is using a finger release; the archers' paradox comes into play.

When an archer releases the string using a traditional finger grip the string will ultimately slide off the fingers and move left creating a leftward thrust on the rear of the arrow, this creates a slight bend in the arrow. The arrow then tries to compensate for this by moving back to the right and then again back to the left in decreasing amounts until the arrow is flying true. The acceleration of the arrow plays a part here. The rear of the arrow has now begun to accelerate and there is a curvature to the shaft. The front of the arrow is resisting, helping to create the 'wobble' that is common among finger shooters. The "wobble" is less pronounced with a release aid and with high spine shafts.

There are ways to reduce or even eliminate the “Archers Paradox” One way to minimize this is to add spin to the arrow by fletching your vanes or feathers with an offset or helical. Another way is to use a release aid. In many cases the use of a release aid can have a dramatic effect on reducing the wobble of the arrow, A.K.A. arrow oscillations. There is always some oscillating no matter what shaft or bow is used. The best we can do is control as much of it as possible. You can view a slow motion video that show the arrow’s oscillations here:

http://www.youtube.com/watch?v=aNI9BG87qcl&feature=player_embedded

Now that the arrow is on its way to the target and is oscillating what we would like most is to dampen the oscillations as quickly as possible. We want our arrow to straighten up and fly right in the least amount of time, thereby maintaining more of the kinetic energy. Depending on the arrows spine, which refers to the stiffness of an arrow shaft this will happen naturally given enough distance, type of fletching and other arrow characteristics.

Your choice of arrow guidance (vanes or feathers) can have a dramatic influence on the flight of your arrow as well. There are different schools of thought regarding this. One school says feathers are better because they are more forgiving. This is somewhat true due to their light weight and increased drag. Feathers tend to have a stabilizing effect giving them a little more jump out of the bow but will reduce velocity more quickly than vanes down range. One disadvantage to feathers is that they are less durable than vanes. Depending on your choice of vane, you will find that vanes are, more durable than feathers.



Front of Center

Front of Center refers to the balance point of the finished arrow.

When feathers are used the Front of Center or F.O.C. is usually moved up, due to the feather’s light weight. The arrow we are tracking has a FOC of 13% which is a percentage that falls within commonly accepted guidelines of around 10 -15%. Too much FOC and we get an arrow point that is too heavy and will cause excessive arrow oscillations. Increasing weight in the front of the arrow reduces spine. Or, for all intents and purposes it makes the arrow weaker and thus will bend or wobble more. Reducing front weight or adding rear weight increases spine. Basically the rear of the arrow is pushing the front and the front is resisting. Feathers tend to “grip” the air better and help to pull the arrow into line. Feathers are still a popular choice among bow hunters and for good reason. They have been used in archery for thousands of years and have stood the test of time. But as we all know, things change and so came the introduction of plastic fletchings or vanes. The debate about vanes or feathers will probably go on forever.

Note of interest: The small sections of a feather that can be separated and put back together are called vanes. So even when you use feathers, you're shooting vanes.



As our arrow leaves the bow, along its flight path we can observe what is often called the “Kick”. It looks almost like the rear of the arrow has jumped out of the bow sideways. This can easily be observed by standing directly behind the archer. After that initial jump the arrow tends to look like it is flying straight. In actuality, the oscillations are still present but usually not visible. Our arrow in this case has large fletchings on it and the oscillations are damped quickly. If we were using very small vanes or feathers we would see the net effect to be poor stabilization. That isn't to say that with a well tuned bow and good form we wouldn't be able to affect this. I don't want to offend any archers who have taken the time to really hone their shooting skills along with their bow tuning skills. What I'm referring to here is the general effects of fletching size. With a little trial and error we can usually find the right size fletching to suit our shooting style.

The Spinning Arrow

A procedure most archers are familiar with is the process of spinning the arrow by way of attaching the fletchings in an offset or helical pattern.

An arrow may already have a predisposition to curve in flight due to shaft asymmetry, a slight curve in the shaft or a poorly aligned broadhead or nock. Any one of these or a combination of one or more can have an effect on arrow flight. All of these together can really mess things up exponentially. In other words add all of these tiny issues together and you can have a big problem. Of course in a perfect world all of our arrows would be perfectly straight and our broadheads would all be true. The world isn't perfect so we compensate for these imperfections by making our arrow spin around its axis. In doing so, the tendency of the arrow to curve its flight path is rotated in all directions, usually resulting in tighter groups. Generally, the faster the arrow is spun the more spot-on the arrow's trajectory will be.

There are 3 ways to fletch an arrow: Straight, Offset or Helical.

A straight fletch is self explanatory and since we are talking about creating spin I won't discuss it here.



Offset and helical are sometimes confused due to the fact that they are both a means to create spin and look similar and, unless examined closely, the difference is barely noticeable.

An offset vane or feather is just that, offset. The base of the vane is still straight but offset along the length of the shaft.



Helical on the other hand actually curves the base of the fletching along the shaft similar to a boat propeller.



The arrow starts at zero rotation but depending on the degree of offset or helical can accelerate its spin quickly.

As the arrow continues on, the spin rate speeds up. There are now two velocities in play, the arrow velocity and the fletching velocity. The fletchings velocity is its rotation at a right angle to the shaft. The drag on the entire arrow is the sum of the arrows speed and the fletchings spin rate. The spin velocity increases until at some point the speed of the arrow is not sufficient to continue the spin acceleration and it will have reached peak rotation speed.

All of this is happening while the arrow is oscillating, complicating all the simple factors that we just talked about. What this means is that there is additional drag on the whole arrow but mostly on the rear of the arrow, where the fletching is, as it bends and wobbles through the air. Part of the drag on the fletching is trying to straighten the arrow out instead of spinning it.

So much for perfect arrow flight.

There are downsides to spinning an arrow. For one thing the energy to spin the arrow has to come from somewhere and that somewhere is arrow speed. The proper amount of spin always (in my humble opinion) cancels out the negatives.

There is no such thing as a perfect arrow or flight. But if we make use of our knowledge and take the time to try a few things, we can make it look perfect. The archery industry is always willing to oblige with the latest and best new advances.

There is so much more to this than can be covered here and I may get in over my head, so I'll leave it at that.

Oh yes, I almost forgot.

Thunk! Home at last.