The Mechanics of Fly Casting 2

By Bob Bolton

Many experienced fly casters will scoff at the idea of science being associated with something so artful as fly casting. They will say the only way to learn to cast really well is from a good instructor and loads of practice. And they are right, especially about the practice part. But it does help to know the science behind what is going on. And the pastime is becoming more scientific all the time.

When people first starting hunting with bows and arrows, they were long bows with feathered wooden arrows and flint broad-heads. You just looked at a target, guessed the range, elevated the arrow just so, and let loose. Modern hunters, with some expert instruction and loads of practice, could hit things. Bows went to re-curve, arrows went to aluminum, broad-heads went to metal, and look at the sport now. Range finders, mult-pinned sights and optical devices, compound bows, carbon arrows, steel broad heads with razor blade cutting surfaces. None of this was well received at first by veteran instinctive hunters like Fred Bear. But if it had started out that way, there would have been far fewer cowboys around.

As a matter of fact, as long as we are talking about bows and arrows, there are quite a few parallels with fly casting. Most things that fly through the air have some points in common. You might think of arrow mass as line weight. You might think of draw length as rod length. You might think of draw weight as rod stiffness. Far fetched? Maybe. But what about bullet mass as line weight. And powder charge as rod stiffness. And barrel length as rod length. Is there a pattern? And in all these cases, technology has increased the art remarkably. A scientific understanding of the technology will help you to fully appreciate it.

Recently, I had the occasion to read an article by a person evaluating a new fly line taper by a well known fly line manufacturer. After a few adjustments in line size he started lauding the praises of this new line. He compared it to another taper on some other rod and a third taper on yet another rod and lavished praise on its ability to cast long or short or fine or whatever. Nary a word as to why. Nor any mention of just how this taper differed from the other lines. Nothing about how this taper effected line motion. Just touchy feely stuff. Ending with – go buy it, it's great. I would have hoped for more than that.

In the Mechanics of Fly Casting 1, we learned something about rod and line dynamics and the laws of Physics. Now, let's have fun with fly lines!

A Short History

In the very early days of fly fishing, lines were nothing more that woven this or that tied to the end of a willow switch. They evolved over the next century or so into lines woven from horse hair or linen and rods got more sophisticated even into cane. Reels were added and the sport was off and running. Lines then evolved to woven silk impregnated with oil or wax, rubbed smooth with pumice, and waxed so they would float. Rods became fine split cane affairs with snake guides that enabled the line to be shot through the guides for greater distance. These rods were carefully matched to the lines to give the proper loading for the rod. Floating dry flies were improved and false casting was used to dry the flies between casts. Fly fishing had become a fine art with sophisticated equipment and artful techniques. This was, as many still consider, the "Golden Age" of fly fishing. But it was expensive. Not unlike the "Golden Age" of shotguns where artfully made side by side double guns were the epitome of that sport. And then along came technology.

Fly lines went from woven silk to tapered nylon with polymer coatings. Then to PVC with little air bubbles to make it float. The old method of letter designation of diameter changed to the present AFTMA method of rating lines by the weight of the first 30 feet. This was because the PVC lines were lighter for a given diameter and the rod responded to the weight of the line when it was loaded rather than the diameter. So to aid in comparing lines to match to rods, the weight method was necessary. Rods changed too because the larger diameter PVC lines had greater air resistance and required stiffer rods to get the same line speeds.

All this was because manufacturing technology could bring down the cost and improve the maintenance free durability enabling the common man with less skill and money to enjoy the sport. It is not the purpose of this article to judge weather all this was an improvement. Was the Browning Auto-5 an improvement over the Winchester 21 S X S double? Definitely not with regards to the art of shooting. But scads of Auto-5's were sold to many who could never afford a quality double gun. Maybe that is just the way it is and there is no good universal explanation. It is true that people who can afford them still buy quality side by side shotguns, split cane rods, and silk lines.

Modern Fly Lines

Ignoring the persistent argument that the modern equipment is not as good as the old, where are we now? Fly lines of today are highly sophisticated PVC affairs which come in a myriad of tapers, weights, and densities. They are designed some to float, some to sink, some for trout, some for bass, some for salt water, and even some that glow in the dark. And so on, and so on. But it is not all magic. There are some

basics here, all of which can be understood slightly better if we know the mechanics involved. Let's allow ourselves to become a fly line and find out why there are so many different individuals.

To begin, with regards to the fly line itself, it only sees the end of the rod and only feels the force and direction applied to the end of the line by the rod and by gravity and wind resistance. It behaves totally as a free body with regards to whatever else is going on in the rod or the fly casters hand. This is not to say these other items are not important, quite the opposite is true. But all this will be covered in the next article on fly rods. With all the emotion around what makes a rod "feel" good, that one promises to be interesting. So on with fly lines.

Line Weight

As stated before, fly lines are now rated by weight. It is given a number designation to represent the weight of the first 30 feet of the line. Why? I don't know except that 30 feet is kind of an average cast. Regardless, it is the bellwether of fly line rating. Figure I. below gives some idea of what that weight is for the different number ratings. There are 1, 2, and 3 weights also not shown on the chart.

AFTMA #	Weight (Grains)	Tolerance
4	120	114-126
5	140	134-146
6	160	152-168
7	185	177-193
8	210	202-218
9	240	230-250
10	280	270-290
11	330	318-342
12	380	368-392

Figure I. AFTMA Line Sizes.

Ignoring for now, the absolute weight, it can be said that the weight of the line does three things. First, it gives some indication as to how the line will load the fly rod. All fly rods have a comfortable range where they can be cast with an optimum deflection. Too much deflection will cause the rod tip path to become difficult to control. Too little deflection, it will become difficult to hold a smoothly accelerating force on the line. The force required to accelerate this line weight is the characteristic that causes the deflection in the rod. The heavier the line, the greater the force required. The greater the force, the stiffer the rod needs to be to produce it with optimum deflection. More on this in the next article.

Secondly, the line weight produces the momentum required to pull along the fly and leader. Being low on mass and high on wind

resistance, the fly and leader become a large impeding force on the movement of the cast. Therefore, the larger and more bulky the fly, the more momentum required to move it forward and so, the heavier the fly line needs to be.

The third thing that line weight does is actually a corollary of the second. Since the line itself has wind resistance, the heavier line with its higher momentum will carry further than a lighter line.

So heavy line equals big flies and/or long distances with longer and stiffer rods. Light lines equal little flies and delicate (slow) presentations at short distances with shorter, more nimble rods. The mid point and average size for all this is a six weight. Most experienced fly casters will tell you it is a good average system to fish medium distances (25-40 feet), average flies (#8 to #16).

Another corollary that is only marginally related to line weight, is that the large rods associated with heavy lines will give you the ability to fight and land large fish. Sometimes, a larger than necessary system will be used for short casts for very large fish, just to have the large rod. Night time Brown Trout fishing is an example. There the casts may be as little as ten feet but the fish can be two feet long. Even though you really don't need a heavy rod to make these casts, a 24 inch brown trout on a 6 pound tippet will bend a 4 or 5 weight rod around to the butt or even break it right off.

In summary, a heavy line has more momentum during the cast. Classically defined, momentum is the tendency of a body in motion to stay in motion. It is characterized by the formula:

Momentum = mass X velocity

So the heavier the line, the greater the mass and the more likely it will stay in motion with a heavy fly and wind resistance trying to slow it down. That is provided you have a rod with enough fortitude to deliver the force required to provide the velocity. Again, rods are for the next article. And I promise, that one will be fun. Enough for weight, now for taper.

Front Taper

Modern fly lines are usually tapered both at the beginning (leader and fly) end and at the reel or backing end. Let's look at floating lines first. The first taper is called the "front" taper for obvious reasons. There is usually a short (one foot or so) section of level line about the same diameter of a shooting line. This is usually around .032" diameter. The next section is tapered so that in it's 6 foot or so length it tapers up in diameter to the nominal level diameter of the main line. In a six weight line this will be around .047". This is sized so that in the next 23 feet, the line will reach the required mass to be rated (for a 6 weight in this case

about 160 grains). Almost all floating fly lines are tapered in this way. There is a lot of hype about differences in this front taper and for the most part, they are exactly that – hype. Nothing in the differences in this front taper would be recognized by any but the most excellent and sensitive fly caster. There is certainly nothing here that would instantly turn a bad caster into a good one. But here is why they are tapered.

Remember momentum. We just talked about it. Lets divide the fly line into 30 one foot long sections and pretend they are glued end to end to form the line. Now lets look at one piece in the fly line – oh, maybe in the middle somewhere. We start at the end of the back cast when everyone in the line is lying out straight but pointing towards the bank. Now something pulls on the first guy in the line, he on the next, and so on until we are all proceeding neatly in line backwards towards the fish. We keep going faster and faster, headed backwards toward the fish at maybe 40 miles an hour. Suddenly someone stops the guy at the end in a flash. And he whips over frontwards towards the fish as number two guy flies past. But number two guy is stopped suddenly by number one guy and flips over. And so on and so on until it gets to me. We were all proceeding along nicely, our mass and velocity allowed us to go along our merry way with the only forces on us being the guy in front, the guy in back and the friction of the air trying to slow us down. Then the guy in front stops and I am hurtled head over heals. The guy in back of me flies on past till I grab him and flip him too. Proceeding down the line, each guy gets flipped over but with less and less force because of the drag of the air and the drag of the guy behind him. So the whole line moving is being slowed down. But the guy at the end of the fly line right ahead of the leader and fly has the hardest job. He has been dragging the leader and fly all that way. The leader and fly have very little mass and, therefore, very little momentum. So they are a real drag. The last guy in line must have just enough momentum left to turn over and pull the leader forward with just enough energy to turn over the leader and gently land the fly on the unsuspecting fish just below the water. Pretty critical process. Like throwing a rock against a barn door with just enough velocity to touch the bottom of the door without making a huge bang. Too much energy at the end, the fly bangs down on the water and scares the poor fish too death. Too little velocity and the fly lines and leader land in a clump 15 feet short of the fish.

Kinda hard to make it happen all just so. So how can we help the process? What if we tapered the fish end of the fly line so that the fly had a greater effect and each section of the line going from the start of the taper towards the fish. Then the line would know it was getting towards the fish and was at the end of the line. The fly would have a greater effect and the whole system would slow and settle nicely even if the

preceding sections were loaded with excess momentum. It would be sort of like throwing that rock into a big pillow at the base of the barn door. A kinder and more forgiving line that will allow for some variance in the beginning of the cast. Cool. That is what the front taper is for. The front taper starts about 7 feet from the fish end and tapers down to about 1 foot from the fish end . That 1 foot of level line is so you can tie a nail knot or two and trim off some tag without screwing up the front taper. In a six weight line the diameter tapers down from the fly line diameter of about .047" to a diameter of about .032" (about a 2 wt. line). These diameters and lengths will wary somewhat, but this is sort of the norm.

As previously stated, fly line manufacturers will all argue that theirs is the best taper. And that there taper will produce more powerful, long distance casts with softer, kinder, presentations. And too a degree, there may be some variance between lines. But any variance here in the front taper pales in comparison to overall line weight and our next subject. And that is "back taper" (or lack of it in the case of double taper lines).

Back Taper

Usually the main body of the line from the front taper to about 30 feet back from the fish end is level. There are some lines where there is a subtle taper to this part and there may be some merit to this to the sophisticated caster, but by and large, line are level in this section. Lines that are called "double taper" or DT are level throughout the body of the line and only have a taper at the other end which is identical to the front taper. This taper is only there in case the front of the line becomes worn or damaged, the line can be reversed and some extra longevity can be gained. This probably almost never happens since time is also a factor in fly line life and both ends age the same.

Then some lines, called WF or weight forward lines, have a back taper. Weight forward does not mean they have more weight forward, rather that they have less weight backward. If there is a back taper, it will start at about 30 feet and continue to taper down in the next 8 or 10 feet to a running line diameter of around .031". Why, you may ask? Well, there are two reasons. The first reason is fairly straight forward. If you are casting a line, the entire weight of the line in the air that you are accelerating will determine the force required to accelerate it. F = m * a from the first article. Given that the rod you have in your hand is designed to apply a certain force to the fly line, there is a limit to how much line you can successfully accelerate to execute a given cast. Since the longer you intend to cast, the more fly line you will have out, and the heavier it will be. This coupled with the fact that the longer the cast, the higher the initial velocity required, and therefore the greater the

acceleration required to get there, you run out of oomph in a hurry. But how can you get a little more distance? Well, since the back part of the fly line doesn't do anything other than providing a link to the front part so you can accelerate it and then turn it over, it doesn't really have to have any momentum. And therefore, it doesn't really need any mass. And therefore it doesn't really need any diameter. So why not taper it down to a smaller diameter? Smaller diameter, less mass, the more of the force goes into the fish end of the line and the faster it goes with the same force input. Bingo, you are halfway there.

To introduce the second reason for a back taper, we must talk about "shooting." To "shoot" a fly line, the fisherman takes advantage of the force he applies to the back end of the fly cast to turn the line over. As we said before, when all the guys in the fly line are flying backwards towards the fish, someone grabs the back guy and flips him over and so on and so on. This flip and each successive on requires a force be put into the system. This force is usually applied by the rod, but not always. If the caster were to keep a bunch of line off the reel and rather on the boat deck, or coiled up in his hand, he could release it just as the line flew past and use that turn over force to accelerate that line and pull it up through the guides and out towards the fish. Each successive guy in the turning over fly line would be slowed by this force and turned over, just not as fast. The merry fish end of the fly line would sail on unknowing except it would go a little further before it got flipped. And the whole cast would go further.

So how does back taper help this. Well, the lighter the line, the more could be pulled up through the guides and out towards the fish. The further the cast would go. And WF lines do shoot better that DT lines because of the back taper.

So why wouldn't anyone always buy a WF line? The reason you would not is that on many smaller streams and creeks, you never need to cast a long distance. And sometimes you need to handle line out past the 30' level section when roll casting or mending line with a nymph or streamer (or God forbid, a pork chop) on the fish end. The skinny section of a WF line doesn't do that well.

So now you know a little about floating fly lines. You know what the front taper is for. You know about line weight. You know the difference between DT lines and WF lines. You know that DT lines are best for shorter casts up to 40 feet or so and they roll and mend better in that range between 30 feet and whatever. You know that WF lines cast better on long casts. But what about all those other lines. What about clear lines and sinking lines? What about saltwater lines and clear creek lines? How about this? If you need a specialty line, you will know

it. I fish almost all the time with a floating line. The reason is that most of the time I am on a trout stream, I will fish dry flies most of the time. Oh, I may switch to a nymph if nothing is rising to dries, or I may strap on a streamer. But you can do all of this with a floating line. It is unlikely that you will switch lines from a floating to a sinking while on the stream. It is possible, just carry another spool or another reel in your vest. But it is a pain in the ass to do it. It takes time. And when you fish nymphs to no rises and all of a sudden a monstrous cadis hatch comes off, you don't want to be messing around changing a line or spool or reel. And if you are fishing with a sinking or sink-tip line, fishing dries is next to impossible. But if you are swinging nymphs to browns or steel head down behind a salmon redd and that's all you are going to do all day, you might want to use a sinking line so you don't have a weight bouncing along scaring fish. Again, you know you need it. So you go buy one. Otherwise, forget it.

So there you have all I know about fly lines. There is much more. But maybe this will get you started.

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