The Rod & The Cast

by
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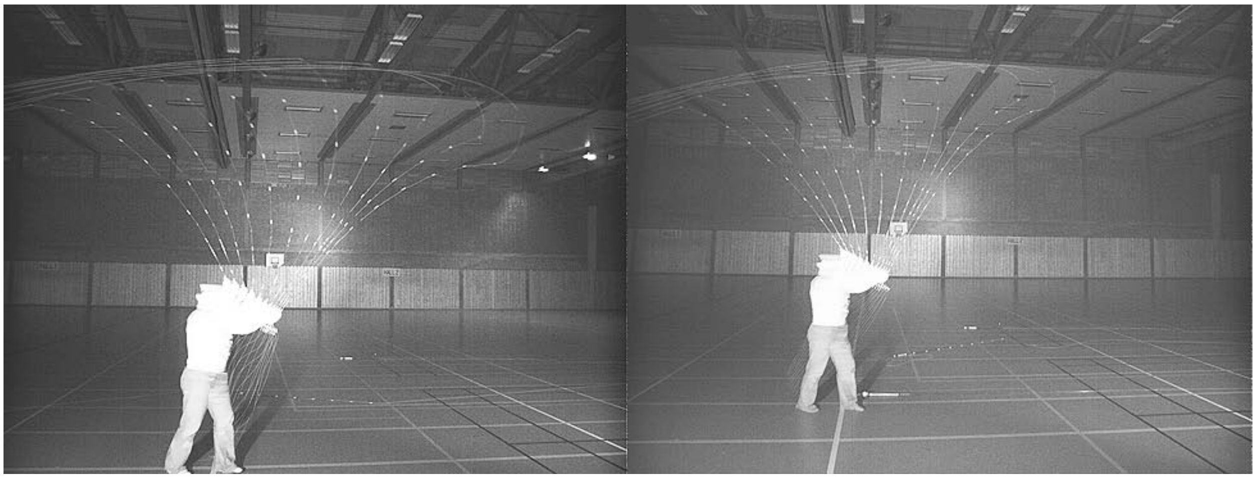


When viewed at normal speeds, fly casting can seem like a blur—the interactions of rod and line taking place in blink-of-the-eye moments. But when fly casting is viewed in tiny increments of time—say 1/500 of a second—its subtleties are more easily studied.

Two of the subtleties that have been of interest to fly casters are the "stop" at the end of the cast and the contribution of rod "spring energy" to the cast. Those two aspects of the cast are the basis for this article.

To gather the needed data, four forward casts made by two well-known Norwegian casters were recorded using a 500 frame-per-second (fps) video system. The rods and line had visual markers, which enabled us to follow the motion of rod and line in time and space. ImageJ and MATLAB software packages were used to do the tracking and number crunching. Each caster made two casts with a Sage TCR and two casts with a T&T Paradigm (both nine-feet long and rated as "five-weights"). Additional, supporting data was gathered in the U.S. using a 200 fps, three-dimensional motion-capture system (with Borger serving as the caster, using a Sage XP and an Orvis Zero-G Tip Flex rod, both nine-feet long and rated as a "five-weights"). All of the casting was performed indoors to eliminate environmental factors such as wind.

The Stop

In fly-casting instruction, significant emphasis is placed on "the stop." It is often said that a well-defined, even abrupt stop of the rod is needed in order to release the spring energy in the rod and to create well-controlled, efficient loops. But what is "the stop?" How abrupt is it? What are its main components? And how do the rod and line respond to "the stop?" Professor Noel Perkins and Bruce Richards have explored some of these questions using the Casting Analyzer, but we wanted to physically see the various actions, and add what information we could to the casting community.

For a cast without a haul (pulling on the line during the cast), the only input from the caster comes from movement of the rod. If we want to be more specific, we can say that the caster moves the butt of the rod using both translation (straight movement) and rotation (rotating movement). The motion of the butt of the rod also results in the tip of the rod moving, as well as the line. "The stop" of the rod, as far as the caster is concerned, therefore comes near the end of the stroke when there is a transition from fast rod-butt movement to "rod-butt stop." Due to the basic laws of physics this "rod-butt stop" cannot happen instantaneously. Let's take a look at what is really going on within the parameters of an "average" cast made with 10 meters of line, plus leader, out of the rod tip.

In **Figure 1** we have plotted the time evolution of certain aspects of a single forward cast, focusing on the "stop time-frame." At first glance there are a lot of lines and letters in there, but we will explain and clarify as we go! The plotted data corresponds to the cast labeled "**Cast #1**" farther down in **Table 1**. Of particular importance is the point denoting "Rod Straight Position" (RSP). This is where the rod first comes straight after unloading (but before the tip dips into counter-flex). This is a well-defined event in the cast and we use it as a reference point for all the given casting data (this is where we have set time (t) in the cast at zero, or t = 0).

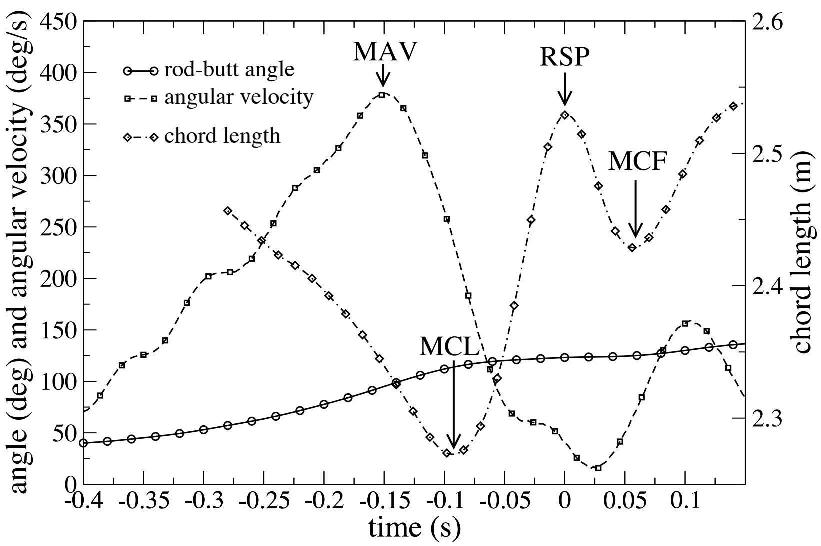


Figure 1. *Plot of the rod-butt angle, angular velocity, and the chord length (distance from rod handle to tip) as function of time through the casting stroke (data is from "Cast #1" in Table 1). The time is relative to the moment when the rod first comes straight after rod unload (labeled RSP, or Rod Straight Position, at t = 0). Labeled events indicated on the graph: MAV = Max Angular Velocity (or peak velocity of the change of the rod-butt angle); MCL = Minimum Chord Length; RSP = Rod Straight Position; MCF = Maximum Counter-Flex (of rod).*

If we now take a closer look at **Figure 1** we can see that the final parts of the forward stroke consist of a sequence of rather well defined events. First the rod hand reaches its maximum speed (not shown on graph), followed by the peak in the angular velocity of the rod butt (MAV). Immediately after that, the rod attains what we are calling Minimum Chord Length (MCL); "chord" being a measurement from the tip of the rod to a point on the rod handle. This is an interesting observation to us, and may a result of the continued rotation of the rod butt past MAV, and its influence on the shape of the bend in the rod. We will be looking at this more closely in future studies. As translation of the rod hand and rotation of the rod butt continue to slow down, the chord length starts to increase again quite rapidly. When the rod butt reaches one-half of its Maximum Angular Velocity (MAV/2), the rod tip is into its un-flexing period. The rod then continues to straighten out until it reaches RSP. As the rod tip passes through RSP it slows down and the speed of the line becomes greater than the speed of the rod tip. As the tip continues its downward path, the line passes above the tip and the nose of the loop is formed. The rod continues into counter-flex and reaches Maximum Counter-Flex (MCF, at the bottom of the trough of the curve) just after the angular velocity of the rod butt passes through its minimum.

This breakdown shows that "the stop," as a whole, does not happened at a single moment in the casting stroke. Of course, to the naked eye, it all seems rather instantaneous, but it really is not. In the casts presented here, "the stop" begins between 0.15 to 0.10 second before Rod Straight Position when the angular rotation and rod hand speed peak. And "the stop," as seen with these casts, lasts until the rod reaches Maximum Counter-Flex around 0.05 second after Rod Straight Position. These timings seem to compare favorably with the data generated by Perkins and Richards using the Casting Analyzer.

Let's take the rod/line measurements a step further and focus on the aspect of "rod spring energy" in the cast. This aspect of casting has been open to debate for some time—essentially, how much does the rod contribute by returning stored "spring energy" during a cast? The fly rod has sometimes been viewed literally as a giant spring, which is "cocked" by the casting motion, and then released when the caster abruptly "stops" the rod. With such a mindset, the cast would appear to be the product mostly of stored energy. But here we can see that there is more happening than just winding up a big spring.

Looking at the graph in **Figure 2** (this is from "**Cast #1**" in **Table 1**) we can see that the rod's chord lengthens most rapidly in the last 0.05 second before Rod Straight Position. In this period, we measure a speed gain of the order of 10-percent (22m/s to 24m/s), which corresponds to 15-percent of the final kinetic energy in the line. The corresponding speed gain from Minimum Chord Length to Rod Straight Position is in the order of 23-percent

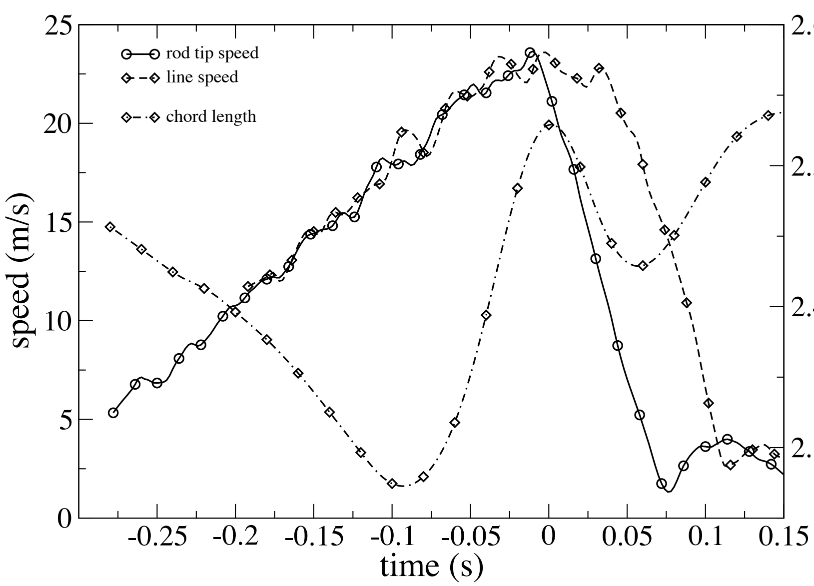


Figure 2. *Rod tip speed, line speed and chord length through the casting stroke. Chord length is shifted and scaled for convenience. Data is from "Cast #1" in Table 1. The "bumpy" appearance of some curves is due to "noise" in the data. Line speed is taken from the first line marker, approximately 0.5-meter from the rod tip.*

(18m/s to 24m/s). And the corresponding speed gain from Maximum Angular Velocity to Rod Straight Position is in the order of 38-percent (15m/s to 24m/s). This last value corresponds to an increase of 61-percent of the final kinetic energy in the line. In the same interval the tip travels close to 2/3 of the total tip path distance (start to RSP). It should also be noted that maximum tip speed appears to occur 0.01 to 0.02 second prior to RSP.

In addition to the calculations performed in relation to the flexible fly rod, we have also generated numbers for Ideal Rigid Lever Speed (ILS). The ILS data pertain to the tip speed of a rigid lever that is moved in the same manner as the butt of the fly rod (both translation and rotation). All four studied casts have ILS data associated with them, as can be seen in **Table 1**. The ILS numbers make for an interesting comparison to the observed tip speeds of the real fly rods at RSP.

	Cast #1		Cast #2		Cast #3		Cast #4	
Event	*t* (s)	v_t (m/s)	*t* (s)	v_t (m/s)	*t* (s)	v_t (m/s)	*t* (s)	v_t (m/s)
MAV	-0.148	15	-0.118	14	-0.159	13	-0.117	14
MCL	-0.093	18	-0.074	18	-0.089	18	-0.072	20
MAV/2	-0.081	19	-0.068	18	-0.086	18	-0.059	21
RSP	0.0	24	0.0	22	0.0	22	0.0	26
MCF	0.058	5	.050	5	0.060	6	0.048	7
ILS	-0.148	19	-0.122	19	-0.162	20	-0.118	22

Table 1. *Explanation of events: MAV = Maximum Angular Velocity (of rod butt); MCL = Minimum Chord Length (tip to handle); MAV/2 = One-half of MAV (point when rod-butt reaches one-half of peak MAV value); RSP = Rod Straight Position; MCF = Maximum Counter-Flex (of rod); ILS = Ideal Rigid Lever Speed (calculated peak speed of a simulated rigid lever (a "broomstick") of equal length as the fly rod, which is translated and rotated in the same manner as the rod butt). Note: Speeds rounded to nearest whole number.*

	Cast #1	Cast #2	Cast #3	Cast #4
Event	% of v_{RSP}	% of v_{RSP}	% of v_{RSP}	% of v_{RSP}
MAV	62	64	59	55
MCL	77	80	83	76
MAV/2	79	81	84	80
ILS	83	84	89	84

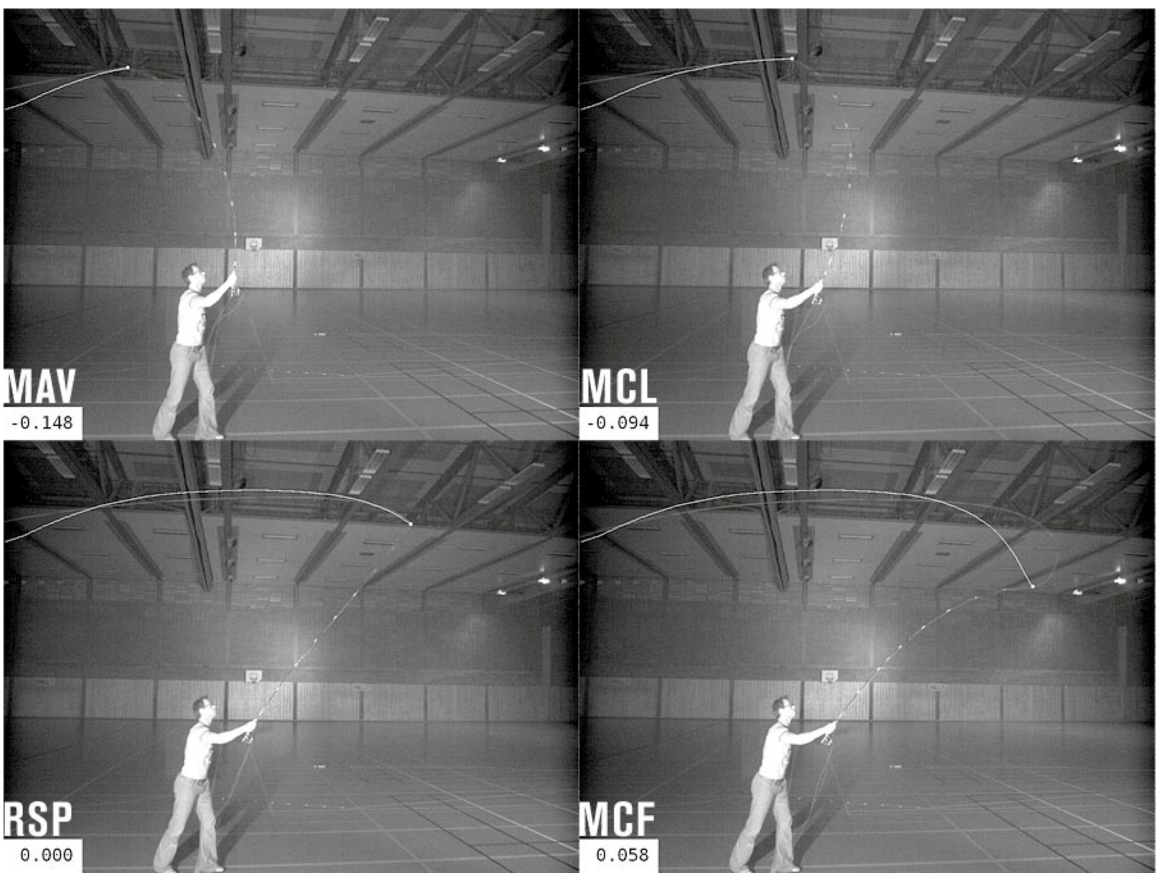
Table 2. *Comparison of the rod-tip speed (shown as a percentage of RSP speed) at selected events in the cast leading up to RSP. ILS data included for reference.*

VIDEO LINKS TO EACH OF THE FOUR STUDIED CASTS:
CAST #1 - CAST #2 - CAST #3 - CAST #4

Looking at these numbers, we do not believe that all of the speed increase in the line from Maximum Angular Velocity to Rod Straight Position comes from stored "spring energy." The reason that we feel this way is that there is still a significant amount of rod rotation (and translation) through the "stop sequence" (from Maximum Angular Velocity leading to Rod Straight Position). This motion is particularly pronounced just as "the stop" begins (just after Maximum Angular Velocity—see **Figure 1**). In other words, the rod butt is still turning and moving ahead while the tip is un-flexing, thus the overall speed increase of the tip is not due solely to "spring." Taking into account the rod butt motion during the "stop sequence," we conclude that in this cast, the speed due to the release of "spring" (potential) energy in the rod is less than a third—and considering that the length of the rod tip path related to rod un-load is approximately 25-percent of the total path length—perhaps on the order of 20-percent (or less) of the overall speed at Rod Straight Position. This conclusion is also backed by the fact that the peak speed of the calculated Ideal Rigid Lever is higher than 80-percent of the RSP speed in all the studied casts (**Table 2**).

These numbers correlate well with the strobe-based fly casting studies published by Ed Mosser and William Buchman under the title "The Dynamics of a Flycast" (*The Flyfisher* magazine, Fall 1980). The Mosser/Buchman article came to an 83-percent "swing," 17-percent "spring" conclusion for the studied cast (using a 12 fps strobe).

In our assessment of these casts, the released spring energy is still a significant component of final tip speed, but it is the lever aspect of the fly rod that is the primary motivating factor. When discussing the rod-as-spring, we should also point out that we expect a greater contribution of "rod-spring energy" during casts that see deeper rod flexure, particularly if those casts are also made using a shorter stroke length and/or narrower casting arc. More research is already underway to investigate rod "spring" in longer-range casts. At the extreme of the "spring energy" realm is the classic Bow-and-Arrow Cast, which has no stroke length and no casting arc, as far the casting



Cast #1 (from Table 1) showing actual moments of MAV, MCL, RSP, and MCF, respectively. The bright white line extending from rod tip is the pathway of rod tip tracked through space. The fly line can be seen as a fainter white line with alternating black sections. The loop can be seen in the MCF frame.

hand is concerned. The Bow-and-Arrow Cast utilizes only the energy stored in the rod to cast the line. Using such a technique, one could say that "spring energy" contributes essentially 100-percent of the "energy of the cast."

In addition to rod flexure providing stored energy, it also allows for a smooth application of power during the cast and it allows the tip to track straighter through the air (making for more efficient loops). A flexible rod also avoids the ILS issue of MAV and maximum tip speed occurring simultaneously, which could have ramifications for aiming.

Conclusion

As we can see in the studied casts, the "stop" (from the perspective of the caster) is a not a single event in the casting stroke, but consists of a sequence of slowdowns while the bent rod unbends. We also see that the caster moving the rod is the primary generator of line speed, with the "spring component" being secondary. It is also apparent in this study that good casters can adapt the stroke to the rod in order to generate the line speed needed for the cast in question.

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