David Alciatore, PhD ("Dr. Dave") **ILLUSTRATED PRINCIPLES**

"Squirt – Part VII: cue test machine results"

***Note**: Supporting narrated video (NV) demonstrations, high-speed video (HSV) clips, and technical proofs (TP), and all of my past articles, can be accessed and viewed online at **billiards.colostate.edu**. The reference numbers used in the article help you locate the resources on the website. If you have a slow or inconvenient Internet connection, you might want to view the resources from a CD-ROM or DVD. See the website for details.*

This is the seventh article in my series dealing with "squirt." So far, we have looked at basic terminology, the physics behind squirt, some experimental results, the effects of follow and draw on squirt and swerve, techniques for compensating one's aim for squirt, low-squirt cues, and tip shape effects. To refresh your memory, **squirt**, also called **deflection**, refers to the angular change in the initial cue ball (CB) direction due to an off-center hit. In other words, when you use English, the CB doesn't go where you are aiming because of squirt. For more background information, see my August '07 article and refer to **NV 4.13** and **NV A.17**. When using English, it is also important to be aware of the effects of **swerve** (see **NV 4.14** and **NV 7.12**) and **throw** (see **NV 4.15**, **NV 4.16**, **NV A.21**, and my August '06 through July '07 articles). Sometimes, the phrase "**effective squirt**" or the term "**squerve**" is used to refer to the net effect of both squirt and swerve on the shift in the CB position at object ball (OB) impact (see my August '07 article for more information). If you want to refer back to any of my past articles, they are all available on my website (***billiards.colostate.edu***).


normal video

NV 4.13 – Squirt due to high speed English
NV 4.14 – English curve due to an elevated cue
NV 4.15 – Using throw to make a partially blocked shot
NV 4.16 – Over-cutting a cut shot to compensate for throw
NV 7.12 – Small-curve massé shot
NV A.17 – Effective squirt vs. speed
NV A.21 – Bank shot using throw and spin transfer

This month, we'll look at some recent experimental data collected with a cue squirt-testing machine I have been working on with a group of mechanical engineering students at Colorado State University. **Diagram 1** shows the first version of the machine. It consists of a spring-loaded carriage on a linear rail that consistently and accurate delivers the cue at a desired speed and CB tip-contact point. This machine is different from previous machines (e.g., Predator's "Iron Willie" and Meucci's "Myth Destroyer") in several ways. First, the cue is held perfectly horizontal throughout the entire stroke (i.e., the cue is not elevated and the stroke is a perfect "piston" motion). This completely eliminates CB swerve as a factor. This is an important feature because swerve can vary with cue elevation, ball speed, shot distance, and ball and cloth conditions, making it difficult to interpret squirt results. Also, no OB is involved so throw is not a factor either. Our machine measures just the squirt characteristics of the cue ... nothing more. You can view a demonstration of how the machine is used by clicking on "CSU cue squirt-testing machine" under "Miscellaneous" in the "Online Video Collection" section of my website. In the remainder of the article, I will show some useful and interesting test results from the machine.

*** **The sponsor of the project asked that the photo no longer be visible in the article. Sorry.** ***

Diagram 1 Cue squirt testing machine

Diagram 2 shows experimental data for squirt measurements taken over a wide range of shot speeds. Many people think squirt is larger at higher speeds than at lower speeds. This "myth" is shown with the red curve in the diagram. As the actual data points show, squirt is very nearly constant over a wide range of speeds, for a given tip offset. This conclusion is in agreement with the "human robot" data presented in my September '07 article. As with all of the graphs in this article, each data point represents the average of five trials taken at each setting (e.g., each speed in Diagram 2). I think one reason people sometimes think squirt increases with speed is because they might be including the effects of swerve in their thinking. "Effective squirt" (AKA "squerve") due to both squirt and swerve does depend quite a bit on shot speed (see my October '07 article). One final observation about Diagram 2: you might notice a small dip in squirt measurements at medium speeds. I'm not sure how to explain this physically, and it could even be a slight error introduced by how the machine functions. Regardless, it is a very small effect. I think it is safe to say that squirt is very nearly constant with speed and doesn't increase with speed as the "myth" curve suggests.

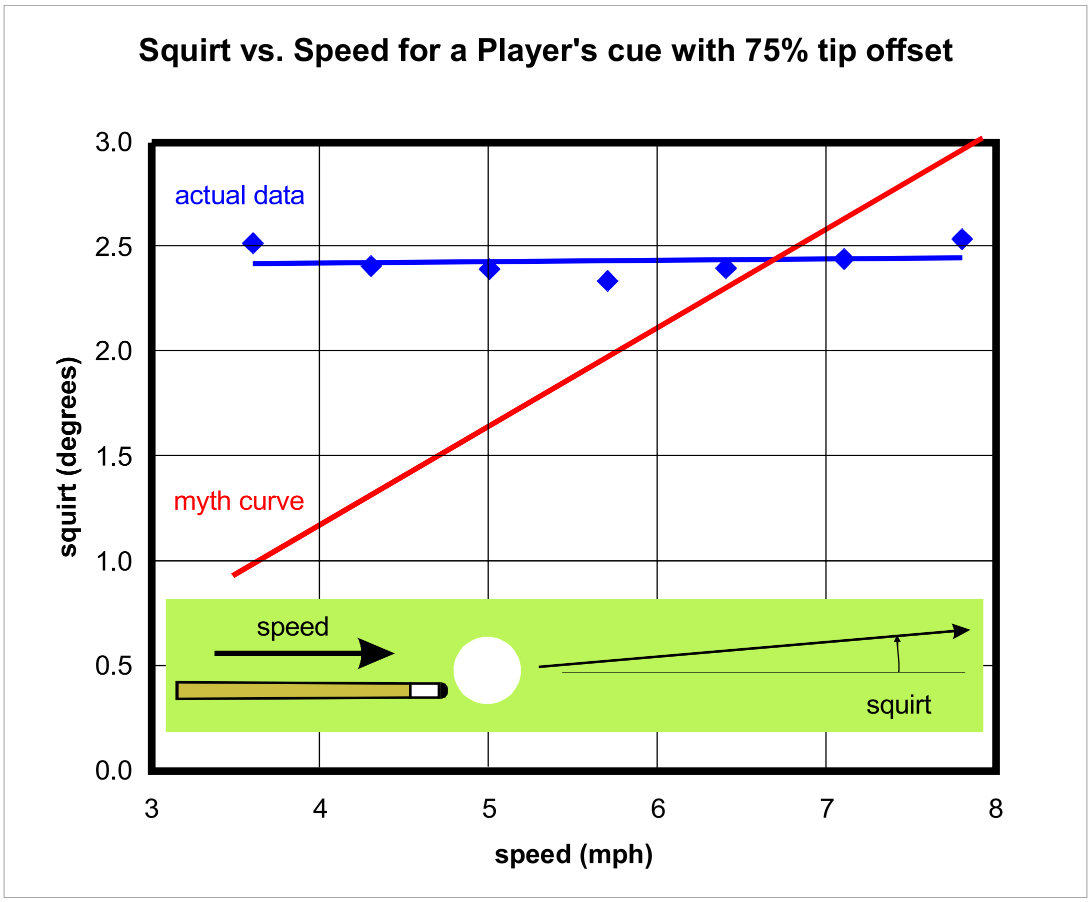


Diagram 2 Squirt vs. speed for a fixed tip offset

Diagram 3 shows squirt measurements for a laminated cue (Meucci) at various cue twist positions. At different twist angles, the wood layers are oriented at different angles relative to the table. The shaft is expected to have different properties (e.g., stiffness) at different twist angles (i.e., cue orientations). Some people think the cue will create different amounts of squirt in different orientations. If this were true, you would expect the squirt to vary somewhat as shown by the red "myth" curve in Diagram 3. One would expect the largest difference between the 0° and 90° orientations, and one would expect the values to be the same at the 0°, 180°, and 360°

orientations, because the wood layers are aligned in the same directions at those twist angles. The actual squirt measurements show that squirt does not vary significantly with the cue orientation. The look, "feel," and sound of the cue might be different in different orientations, but the data clearly shows that the squirt is nearly constant for all orientations. These results are backed up by the theory (see **TP A.31**), which predicts the squirt varies only with the effective "end-mass" of the cue. The "end-mass" might vary slightly with orientation due to slight stiffness variation (see TP A.31), but the effect is obviously not significant in the data.


technical proof

TP A.31 – The physics of squirt

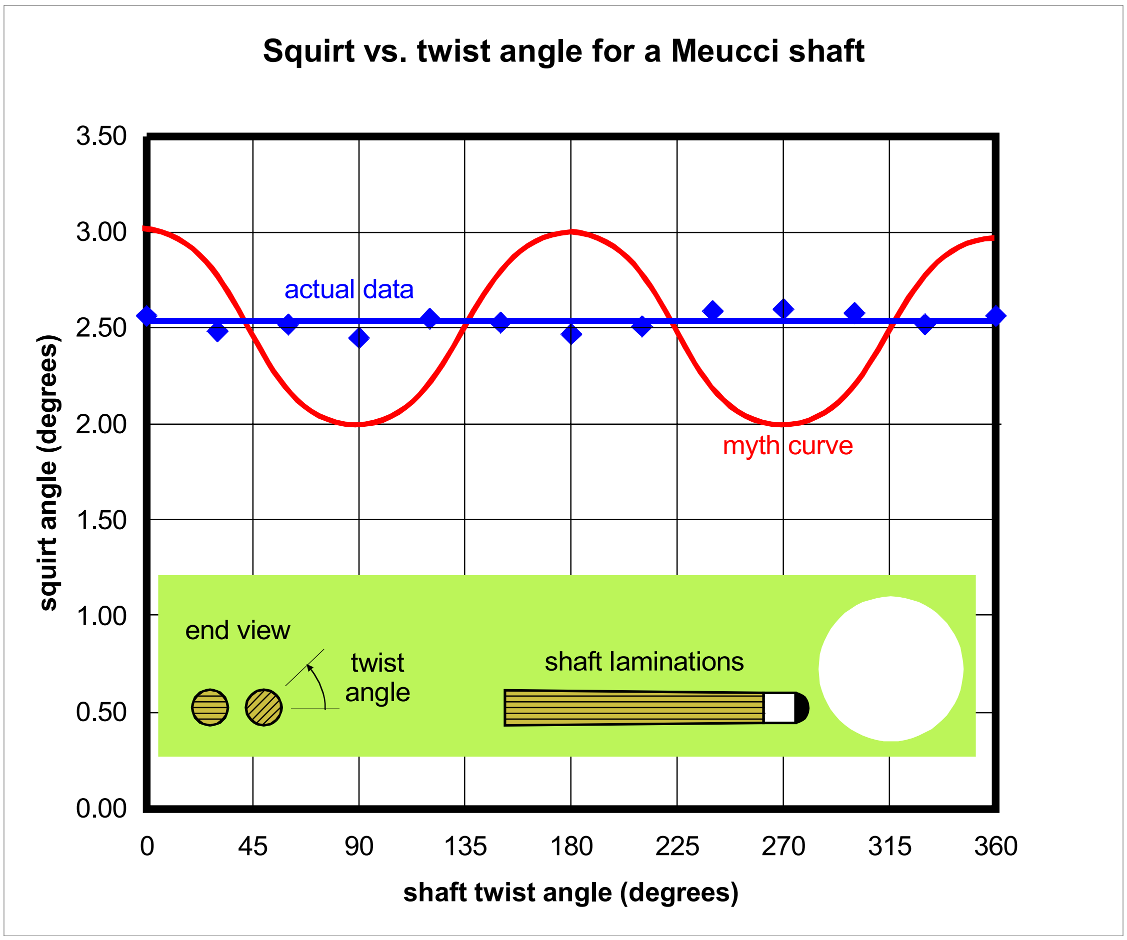


Diagram 3 Squirt vs. laminated-shaft twist angle

Diagram 4 shows the results of a classic experiment to show how end-mass affects a cue's squirt. In the experiment, a mass is added to the cue at different positions. When the mass is close to the tip, the effect on the squirt is the largest; and when the added mass is more than a certain distance from the tip, the added mass has no effect on the amount of squirt. People who believe cue stiffness is what causes squirt, and end-mass has no effect, would predict the red "myth" curve shown in the diagram. The two sets of actual data (the green and blue curves) show the end-mass effect very clearly. The "masses" used in the experiment are two sizes of standard binder clips (available at any office supply store). The clips attach to the cue rigidly and can be easily shifted along the cue. The small binder clip was weighed in at 0.3 grams (0.011

ounces), and the larger clip weighed in at 1.1 grams (0.039 ounces). The results show that the more mass you add to the end of the cue, and the closer the mass is to the tip, the more the cue will squirt. Also, if mass is added beyond a certain distance from the tip, it has no effect on the squirt. For the Players cue I tested, the distance was about 7 inches. Notice how the curves level out to the same squirt value beyond the 7 inches, regardless of the amount of the added mass. The results of this experiment explain why manufacturers have been able to create “low-squirt” cues by using a smaller diameter shaft, drilling out the end of the shaft, and/or using a lighter ferrule. All of these modifications reduce the end-mass of the cue (see my December ’07 article for more information).

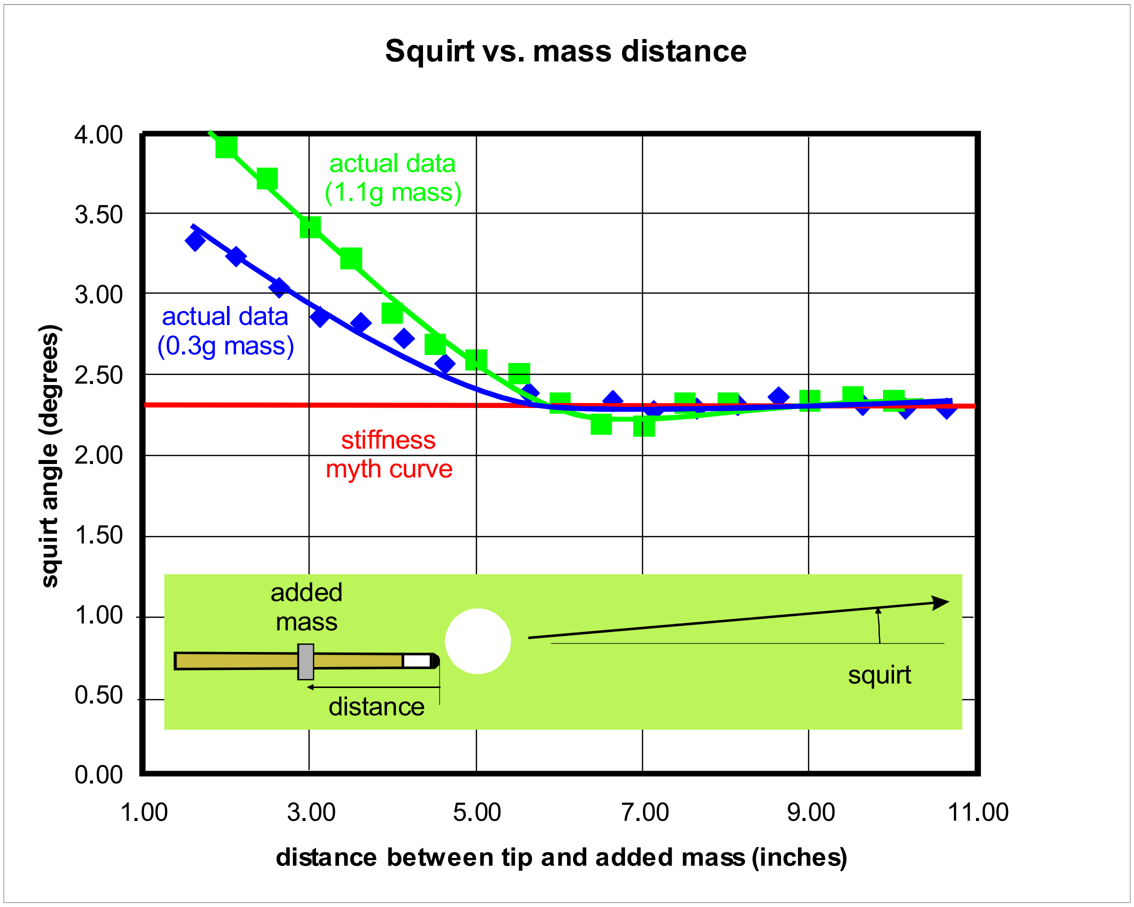
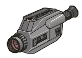


Diagram 4 **Squirt vs. position of added mass**

One more thing to note in Diagram 4 is how the squirt seemed to dip a little lower for the larger added mass, before flattening out. When we first saw this, we wondered if adding even more mass at this magic point would reduce the squirt even further. If that were the case, we might have discovered a new way to make a low-squirt cue. Unfortunately, adding more mass at that point did not cause additional decreases in squirt. Bummer!

If you want to see an exaggerated example of the effect of end-mass on squirt, see **NV B.1**. Near the end of the video, Mike Page uses a pair of vise grips to add significant mass and squirt to a cue. The effect is dramatic ... check it out. I don’t recommend using vise grips at home, because you might damage your cue, but binder clips are easy to come by and won’t cause damage if you are careful. Give it a try.


normal video

NV B.1 – Mike Page's squirt and swerve video

I hope you are enjoying and learning from my series on squirt. Next month, I'll conclude the series by summarizing many important conclusions about the combined effects of squirt and swerve.

Good luck with your game,
Dr. Dave

PS: I know other authors and I tend to use lots of terminology (e.g., squirt, throw, cling, stun, tangent line, 30º rule, etc.), and I know not all readers are totally familiar with these terms. If you ever come across a word or phrase you don't fully understand, please refer to the online glossary in the "Instructor and Student Resources" section of my website.

PS: I just released a new DVD called "*High-speed Video Magic*." It features billiards, but it also includes stupid human and animal tricks, balloons popping and bouncing, things breaking, engineering stuff, toy physics, and fluids and foods in motion. For more information and video excerpts, see the website (*billiards.colostate.edu*).

Dr. Dave is a mechanical engineering professor at Colorado State University in Fort Collins, CO. He is also author of the book, DVD, and CD-ROM: "The Illustrated Principles of Pool and Billiards," and the DVD: "High-speed Video Magic."