David Alciatore, PhD ("Dr. Dave")

"Draw Shot Physics - Part II: examples"

*__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. Details can be found online at: **dr-dave-billiards.com**.*

This is the second article in a series on draw shot physics. Last month, we looked at some of the basics and listed a set of conclusions from a thorough physics analysis (**TP B.8**). This month, I want to present some detailed results and show some specific examples that illustrate some of the conclusions. With a straight-on draw shot (with no cut angle), the draw distance is determined solely by the amount of spin the cue ball (CB) has at contact with the object ball (OB). It is important to distinguish between how much spin the CB has off the tip and how much it has at OB contact, after some spin is lost due to "drag" on the cloth. **Diagram 1** shows how much spin the cue delivers to the CB for different tip offsets. With a small offset (i.e., close to a center-ball hit), the CB will have very little spin (point "A"). Obviously, as you increase tip offset, the amount of spin increases. At point "B" (at about 30% tip offset), you get about 50% of maximum spin; and at point "C" (50% offset), you get about 75% of maximum spin. Maximum spin occurs at the miscue limit (point "D"), but the gain in spin is smaller as you approach the miscue limit (i.e., you only get a little extra spin by increasing the tip offset close to the miscue limit).

TP B.8 – Draw shot physics

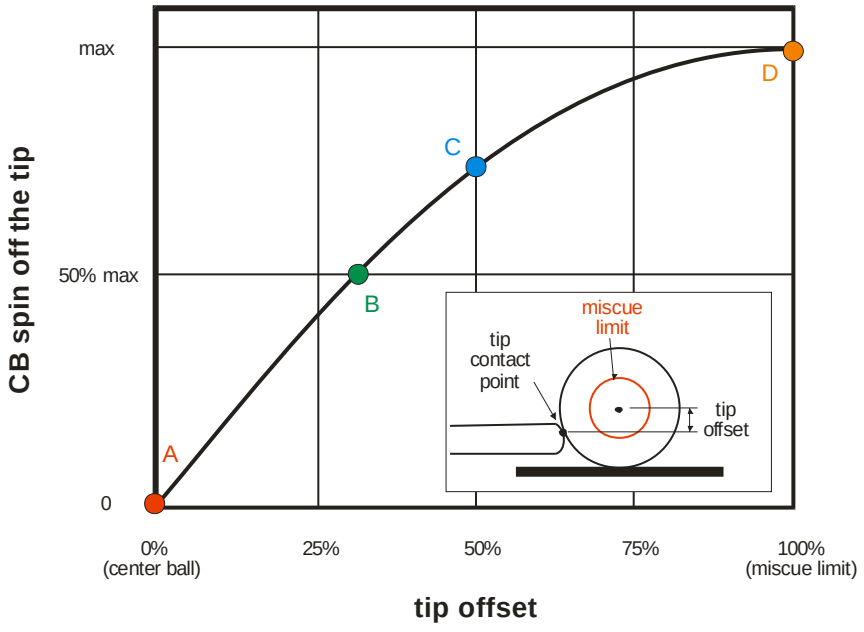

Diagram 1 Spin vs. tip offset

Diagram 2 shows how the CB spin and speed change during drag on the way to the OB (see also: **HSV 3.1** and **NV B.10**). The straight arrows in the diagram represent the CB's forward (translational) speed, and the curved arrows represent the CB's spin rate (rotation). As the CB slides across the cloth, a rubbing drag force is created. This "drag" slows both the CB's forward speed and spin rate, as shown in the diagram by the shortening of the arrows. The amount of CB draw depends on how much spin the CB has when it strikes the OB. In Diagram 2a, the CB is hit at maximum (100%) tip offset. This results in the most spin off the tip (per Diagram 1 above); but because some the cue's energy goes into spinning the ball, less is available to move the ball forward, so the CB's forward speed is less than that of a center-ball hit with the same cue speed. Diagram 2b shows what happens with an 80% tip offset. As shown in Diagram 1, the spin will be a little less than with the 100% offset, but the CB's forward speed will be faster. CB speed and spin decrease at nearly a constant rate during drag. Therefore, at a faster speed, less spin will be lost over a given distance. In this case, the 80% offset shot results in more CB spin at OB contact than the 100% offset shot, even though the 100% offset shot has slightly more spin to begin with.

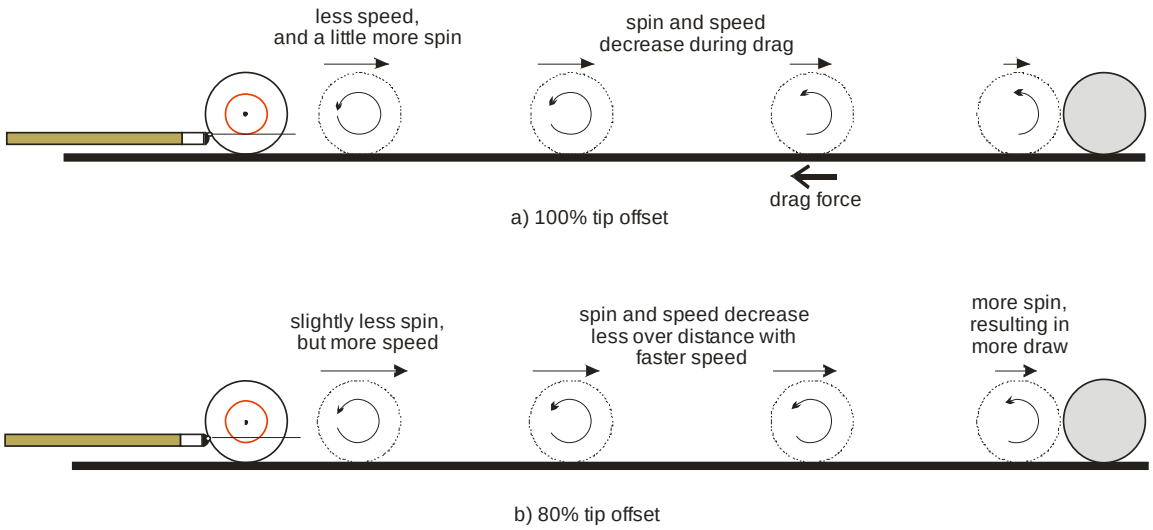

Diagram 2 Spin and speed loss with drag

high-speed video

HSV 3.1 – Stop-shot showing loss of bottom spin over distance

normal video

NV B.10 – Drag spin loss and English persistence

Diagram 3 shows how draw distance varies with tip offset for firm shots with medium and large drag distances. As illustrated in the inset figure, **drag distance** is how far the CB travels to the OB and **draw distance** is how far the CB draws back after impact. With shorter drag distances, more tip offset produces more draw; but as the drag distance increases, the draw distance can actually be longer with less tip offset (e.g., 80% vs. 100%), assuming enough cue speed is being used to retain bottom spin at OB contact. Points "a" and "b" in Diagram 3 correspond to the examples in Diagram 2. With a power draw shot (long drag distance, and fast speed for long draw distance), you will get more draw if you hit slightly above the miscue limit (at 80% tip offset) instead of at the miscue limit (100% tip offset). In other words, you don't always

get more power draw by hitting closer to the miscue limit. Increasing cue speed will always increase the amount of draw, but increasing tip offset doesn't always help. This is one of the interesting conclusions summarized in last month's article that might not have been "intuitively obvious to all.

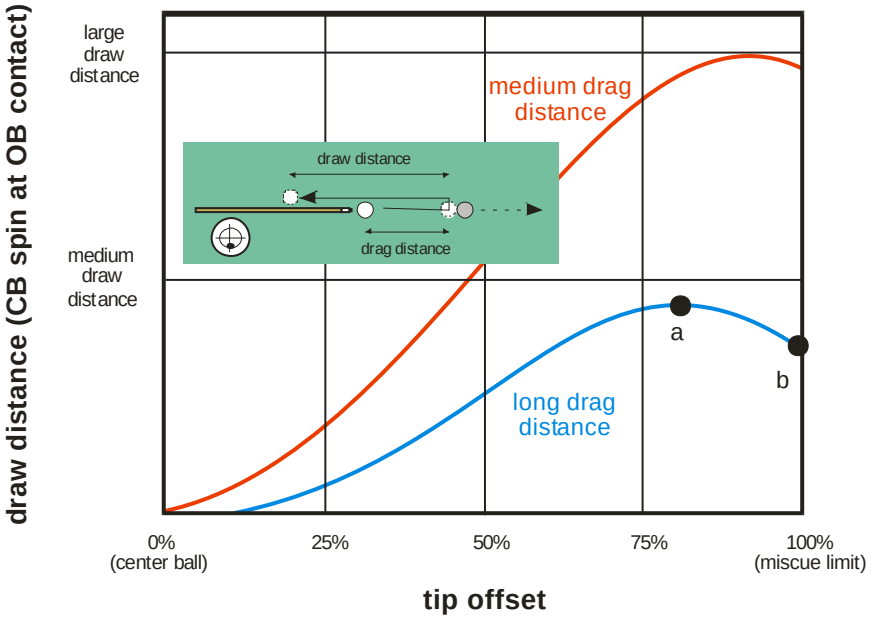

Diagram 3 Draw distance vs. tip offset for power shots

Diagram 4 shows several examples that illustrate a few of the conclusions summarized last month. The 1-ball and 2-ball shots illustrate what was just described above for a power draw shot. The 1-ball and 2-ball shots correspond to shots "a" and "b" in Diagram 2 and points "a" and "b" in Diagrams 3. The 3-ball and 4-ball shots illustrate how, for draw shots with medium to long draw distance, you can generally achieve better draw distance control by hitting the CB lower and harder rather than higher and softer. The double-headed arrows show the range of possible final CB positions that would result from being a little off with your speed or tip offset. The 3-ball shot shows better draw distance control (smaller range). The 5-ball and 6-ball shots illustrate CB draw distance control for a stun-back shot, where you wish to draw the CB back only a small amount (e.g., 1-3 inches). Here, you will generally have better distance control by hitting the CB harder and closer to center rather than softer with a larger offset. The main reason for this is the drag action will have much less time to affect the CB's spin (due to the faster speed). Another possible factor not considered in my analysis concerns the ability to judge the speed and tip offset required for softer shots. For some people, being closer to center-ball at a faster speed will be more comfortable and result in better stun-back distance control, regardless of the physics.

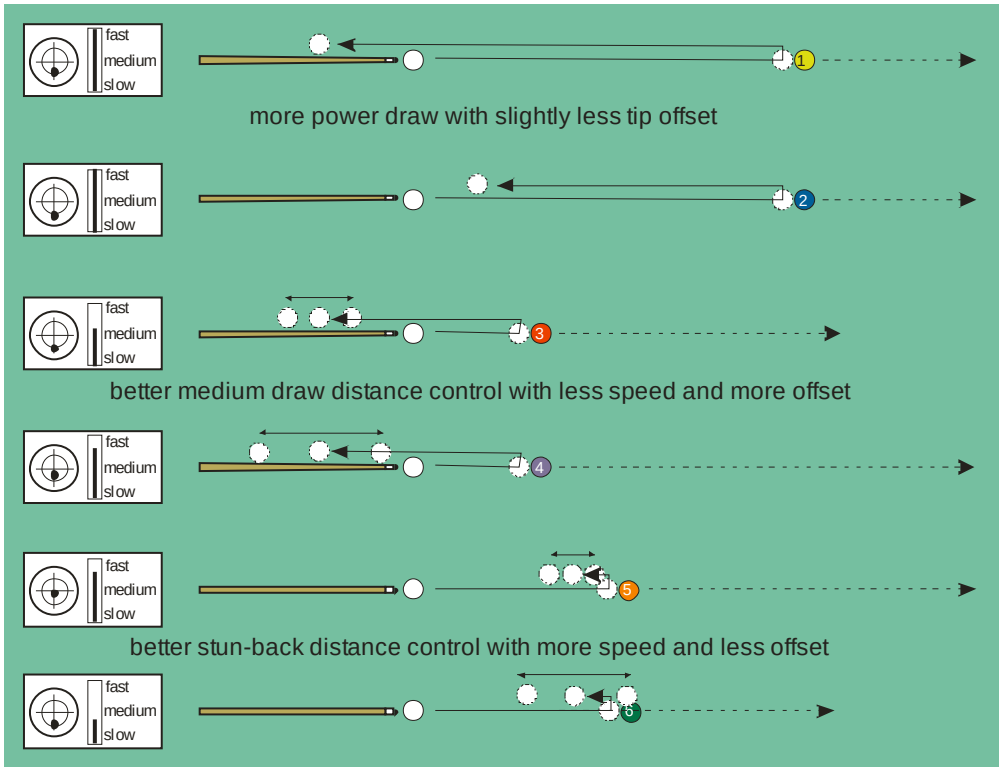

Diagram 4 Shot examples

The analysis and examples above have considered only CB spin at OB impact. It turns out the speed of the CB at OB impact can also be important. This speed does not affect the amount of CB draw, but it does obviously affect the speed of the OB. For a straight-on shot, nearly all of the CB's forward speed is transferred to the OB. One advantage of a slower OB speed is: the effective "size" of the pocket will be larger (see my November '04 through January '05 articles); therefore, your margin for error will be larger with a softer shot. Also, with more speed, people generally lose a little stroking line and tip-placement accuracy. Another advantage of slower speed is: if you cut the CB a little by accident (for a straight shot), the CB won't drift sideways as much (e.g., if you wish to hold the CB's position for the next shot).

Well, I hope you look forward to the remainder of my series of articles dealing with the draw shot. In future months, we will look at the importance of the ratio of CB spin and speed, the effects of cue elevation, and cut angle considerations.

Good luck with your game,
Dr. Dave

PS:

- If you want to refer to any of my previous articles and resources, you can access them online at ***billiards.colostate.edu***.
- I know other authors and I tend to use lots of terminology (e.g., squirt, throw, stun, impact line, 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 on my website.

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."