PowerGlide

From The PowerGlide Lab
Mr Bumble Gets to the End of the Cue

In the very first blog from the PowerGlide Lab an ill-fated bee helped to show how elasticity is an intrinsic factor in the collisions occurring in cue sports. Now to discuss how that fact influences the design of cues themselves. Unlike Oliver Twist, we've got more from Mr Bumble!

As our apian hero indirectly demonstrated, the elasticity in a cue causes the impact of a shot to initiate compression waves. To determine how these waves might affect a cue's performance we need an idea of the length of time the tip is in contact with a cue ball. Both experiment and theory have indicated this is typically between 1 and 2 milliseconds, depending on the power of the shot and the hardness of the tip material.

The speed of a longitudinal compression wave, effectively the speed of sound, in cue woods such as ash or maple is between 4000 and 5000m/s. Hence, even for a relatively short duration impact shot of 1 millisecond, this wave will have had time to travel at least 4m, more than enough for it to go all the way up the cue and back down again. This confirms what players instinctively feel, that the construction of the whole cue, all the way along to the butt, will contribute to its playing characteristics.

This conclusion requires we now clarify the previous blog's statement that "the compression wave may not have time to travel far very down the cue before the cue ball has left the tip, which means the characteristics of that small part of the cue alone will do much to determine the nature of ball's motion". We can now see this consideration does not apply to the longitudinal compression wave. However there is another sort of compressibility-dependent wave to consider, the transverse wave.

The transverse wave travels at a much slower speed than the longitudinal wave. To give a rough idea of just how much slower, we can simplify a cue as a uniform thin circular rod or bar vibrating freely, in which case the fundamental mode of vibration should have a frequency around that given by the formula shown in the diagram.

For an ash or maple bar 1.5m long and 2cms in diameter, the formula gives a fundamental frequency for an unrestrained ("free-free") vibration of about 30Hz (cycles/sec). The diagram also shows that a full fundamental wavelength is about 1.6 bar lengths, so 2.4m. Multiplying this by 30Hz gives a wave speed of 72m/s. Thus even in a 2 millisecond impact this transverse wave would only travel around 14cms.

PowerGlide

Transverse waves will be particularly excited when striking an object ball off-centre to impart spin. Thus the characteristics of the last few cms of the cue will indeed "do much to determine the nature of ball's motion" for such shots. In this context two characteristics of the end of the cue are of particular import, mass and stiffness.
A cue with a thicker, stiffer, end may yield greater ball speed, but may also throw the cue ball off-line (what pool players call "squirt") more than a cue with a lighter, more flexible end. Because it is at the very end of the cue, the ferrule plays a significant role here, a heavy ferrule obviously adding to the cue end mass.

The 14cms figure above also has other consequences, such as indicating that the bridge hand may well be too far back to have any influence on how the transverse vibration affects the direction of the cue ball. Moreover, by the time such vibrations are felt by the player's back grip hand, the ball will be well on its way, meaning gripping harder then can have no effect on the shot.

On the subject of gripping harder, should this ill-advisedly reach the level of vice-like, the fundamental transverse vibration wavelength would have to be longer and the frequency slower, as the cue would not be "free-free" but "cantilevered". Which gives rise to an apparent conundrum as the wave wouldn't have time to get down the cue to "know" that during the length of the impact. The answer here is that it would then be the secondary or even higher vibration modes that were excited..

Whichever of the higher vibration modes are excited, as can be seen from the diagram for the secondary, when the frequency goes up, the wavelength goes down, which results in the speed of the relevant wave, and hence the length of the cue that can affect the shot through it, remaining relatively fixed.

But that's enough of theory and numbers and formulae, at least for this time (be warned, the PowerGlide Lab has plenty more where they came from!). Let's sum up with the simple overall conclusion that the design of the whole cue can determine its power and feel on centre-ball striking shots, but the design of the end portion alone will be critical when it comes to the allowing for the effects of imparting spin.

And that's how Mr Bumble gets to the end of the cue!