Q: Bow symmetry (Geo Kloppel)

Hi Knut, I understand that when a bow is warped to one side or the other, this breaks its left/right mirror symmetry, opening the way for out-of-plane motions to couple undesirably with the proper motion of the stick, confounding the player's efforts to control its behavior. I assume that the strength of such coupling is sensitive to the degree of the warp, since no real bow is perfectly symmetrical. I have a repairman's experience-based sense of how much warp can be tolerated, and a bowmaker's practical sense of how hard one should strive to achieve symmetry, but I'm wondering if there's any straightforward way to quantify or measure the consequences of this kind of asymmetry? (There's a related question of twist as a symmetry breaker, which is of considerable practical importance in the repair shop, as many bows of all qualities show detectable degrees of twist.) Also, I've watched some fine players test bows by bowing slow full-length legato strokes in such a way that the stick bends out prominently to the side. This looks like a technique for applying bow force in excess of the limit that one can exert within the plane of symmetry without "touchdown" (playing on the wood). But I can't rule out that it's a deliberate breaking of the symmetry of the bow for some other evaluative purpose, especially since the last guy I watched doing this was feeling-out the bow for a "weakness" caused by a visible flat spot in the stick (a fine old TUBBS cello bow). Any thoughts about this?

A: (Knut Guettler)

Hi Geo!

Frédéric Ablitzer, Jean-Pierre Dalmont, and Nicolas Dauchez published recently (JASA, January 2012) an article with the title "Static model of a violin bow: Influence of camber and hair tension on mechanical behavior", where some of the issues you were mentioning are discussed (Ref. 1), although without analyses of *dynamic* behavior. In order to provide the best possible answers to your questions, I contacted them with an invitation to join the discussion. I just received a comment from Frédéric, who indicates that he is going to look a little deeper into the problem you present, after having done some more simulations with his program. A new article on bow statics has also been submitted and will be published in Acta Acustica u.w. Acustica.

Thank you for bringing these topics up for discussion; I believe quite a few of us are interested in learning more about this!

Before presenting his present reply, I thought maybe it is a good idea to look at the bow's simplified geometry for a second.

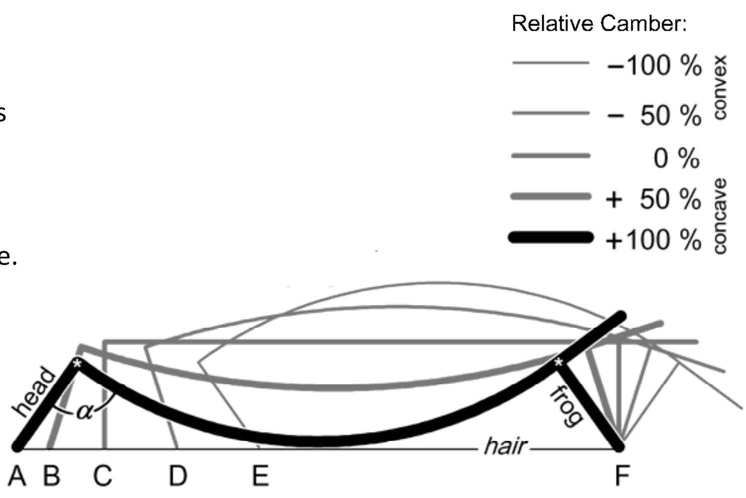

Figure 1:
Simplified geometry of a bow: circular camber; fixed frog and head angles. As the camber goes from concave to convex in equal steps, the distance between the tip and the frog's ferrule (F) decreases in steps of *increasing* size. With concern to the distance between the head and the frog at the stick (marked with *), the distance is greatest when the stick is straight, and when bent to either side in equal steps, the distance is shortened with steps of *increasing* size.

I am presenting Figure 1 in order to point out that the more the stick goes toward convex—or for that matter, bends out to one side of the symmetry line—the less resistance it provides against the tension of the hair. In the figure, each step (A – B, B – C, etc.) will result from the same tensional increment, as the bow goes progressively “weaker”.

Knut

Ref. 1: F. Ablitzer, J.-P. Dalmont and N. Dauchet, "Static model of a violin bow: Influence of camber and hair tension on mechanical behavior" J. Acoust. Soc. Am. **131 (1), Pt. 2**, 773 - 782 (2012). (See “Library”)

A: (Frédéric Ablitzer)

Let us first consider a stick which is not warped. When tightening the bow, the stick remains in the plane as it straightens. The playing hair tension is denoted T0.

If a pure vertical force is exerted (upwards Knut’s comment) at the tip of the tightened bow, the stick bends in the plane and the hair tension increases (T > T0), because the distance between the two endpoints of the hair slightly increases (you can observe the rise in hair tension as you load the bow at the tip simply by plucking the hair and hearing the tone which gets higher as the load increases). The vertical force makes the in-plane curvature increase, whereas the rise in hair tension makes the in-plane curvature decrease.

If a pure lateral force (90° / vertical axis) is exerted at the tip, the stick bends laterally, which makes the distance between the endpoints of the hair slightly decrease : thus, the hair tension decreases (T < T0). The lateral force makes the "out-of-plane" curvature increase, the decreasing tension makes the "in-plane" curvature increase.

This second case illustrates the fact that a coupling between vertical and lateral bending of the stick occurs as soon as the stick has an out-of-plane motion (here due to lateral loading, since the stick was initially not warped). The coupling between vertical and lateral motion of the bow is due to the variations in hair tension (the hair acts as a spring along its direction, in response to the varying distance between its endpoints), which generates an additional bending of the stick.

In the case of a slightly inclined force (e.g. 30° / vertical axis), as when the player tilts the bow during playing, the coupling between vertical and lateral bending also exists, but the motion of the stick - and the compliance felt by the player - is still symmetrical (it is the same when applying a force at 30° or -30°).

Now, when the stick is warped: First, tightening the bow amplifies the initial warp : the increase in hair tension up to T0 makes the "in-plane" curvature decrease, but the "out-of-plane" curvature increase. Then, when the tightened bow is loaded by a pure vertical force, lateral bending also occurs. Moreover, the behavior of the bow is no longer symmetrical when applying the force to one side or the other.

Frédéric