Q: Varieties of bow hair (Geo Kloppel)

Hi Knut!
I'm particularly happy to have this opportunity to ask a bassist-turned- acoustician this next question: Double bass players often have strong preferences concerning bow hair. Black hair, white hair, salt-and-pepper hair, brown hair, red hair... The string is colorblind, of course, but textural differences do exist, and they do correlate roughly with color. My question is, how do these differences relate to sound production? Can you suggest any general guidelines for the selection of hair among these alternatives? Cheers!
Geo Kloppel

A: (Knut Guettler)

Hi Geo!
I have heard and believed in a lot of what has being said about bow hairs over the years. So, with the belief that black hair has coarser scales; I was using that for many years.

However, having been involved in acoustics, I now know that coarseness of hair scales has very little to do with playability: For a string to get started there must be a dynamic change of friction over each individual stick-slip period. Hair scales would only provide a fixed friction, a “DC component” if you like thinking in electrical terms. Any player, who has tried playing with unrosined hair, must have noticed how difficult it is to get the string to speak. Hair scales stand up no more than about 0.5 µm, that is 1/2000 of a millimeter; far too little to have any noticeable impact on the string movement. And if it had, it would only have pulled the string a little to one side and kept the equilibrium there…

In my article from 2011: "How does rosin affect sound?" (Ref 1), I discuss these matters. The bottom line seems to be that rather than surface roughness it is the hair’s chemical ability to hold rosin that is the issue here (Ref. 2).

But sure, there probably are structural differences between hair from different horses: One explanation I have heard, is that *white* hair, unlike *black* or *dark* hair, sometimes is bleached (particularly if originating from stallions, for obvious reasons), and that the bleaching process might weaken the hair, making it break more easily if forcefully played, like it would on a bass. If so, the color should be an argument in favor of dark hair for heavy instruments.

But, only related to strength and durability!

Knut

Ref. 1: K. Guettler, "How does rosin affect sound?" (Ref 1.) ASTA String Research Journal (II), pp 37 – 47 (2011).

Ref. 2: F. Rocaboy, “The structure of bow-hair fibres” Catgut Acoust. Soc. J. 1(6), 34-36 (1990).

C: (Geo Kloppel)

Hi Knut, Your remarks about microscopic hair scales accord with my own understanding, and I've never heard anyone suggest that bleaching was anything but harmful to the hair, but I wonder if you've overlooked the most striking structural difference between black hair and white? If you measure the diameters of a large enough number of individual hairs, you find that black hairs average thicker at the butt end than white ones. In consequence they feel stiffer in your fingers, and every irregularity of the shaft stands up more prominently. These are macroscopic textural differences, and I would like to know what effects if any they might have on sound production

(perhaps adding a disruptive element that alters differential stick-slip behavior across the width of the ribbon)?
Geo Kloppel

A: (Knut Guettler)

If scales were raised enough to be "felt" by the string, it would have exactly the same effect as the dusty, glassy particles thrown around on the hair surface (described in my ASTA String research Journal, article): essentially pink noise. If you let me have a day or two, I shall try to produce sound examples of this. I prefer to wait with uploading my reply until I have those ready.
Knut

C: (Geo Kloppel)

Hi Knut,

I'm not talking about scales, I'm talking about much larger textural features. Many hair shafts depart quite visibly from the smoothly cylindrical ideal. This is especially true of the coarsest black hair, which can be quite rough between the fingers. I agree that "noise" would be the essential result of any surface features that were large enough to be felt by the string. What I'm asking is if the different varieties of "noisiness" that different sorts of hair might produce could present the performer with acoustically significant choices. For example, might the presence of "noisemakers" in the hair have some effect on bowing transients?

Kindest regards, Geo

C: (Knut Guettler)

O.K. Sorry for the misunderstanding! Rocaboy measured admittedly white hairs only, where the surface didn't show the kind of structures you are referring to. However, such irregularities will have comparable effects; they will create some sort of noise. The interesting part with noise is that it excites and emphasizes all the major modes of the instrument, regardless of which pitch being played; i.e., it always provides a certain instrumental fingerprint (see Fig. 1). For harsh sounding instruments, the fingerprint will be harsh for every note played, and vice versa. By exciting the instrument's bridge with pink noise—or simply by bowing the bridge, producing hiss only—you'll get an idea of what the signature is.

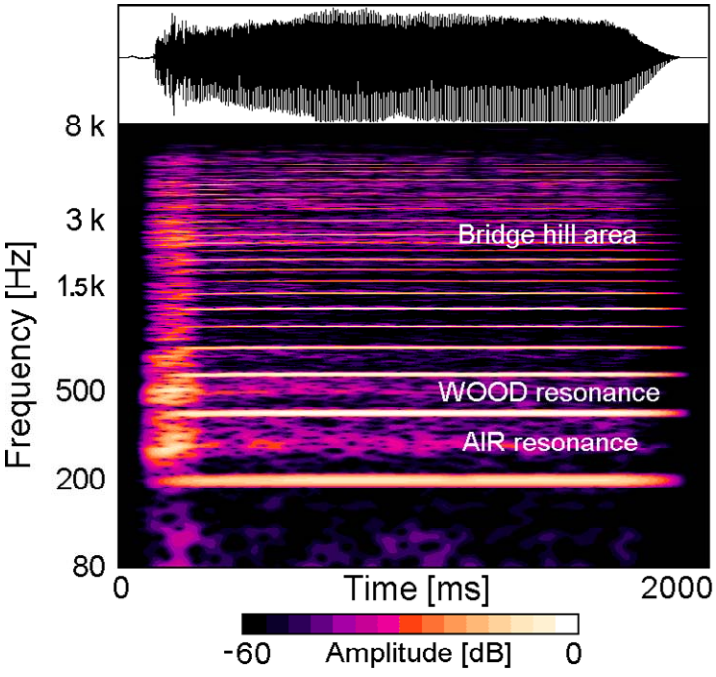

Figure 1: Spectrogram of a quite noisy attack on an open violin G-string. Bright horizontal lines indicate the fundamental frequency (196 Hz) with harmonic overtones (multiples of 196 Hz) above. Notice that in between these, pronounced activity can be seen in certain areas, primarily around the Helmholtz (air-cavity, ca 270 Hz) resonance; the lowest wood resonance (ca 480 Hz); and in the Bridge-Hill region. When the string signal contains much noise—as in this particular attack—the mode frequencies stand out with greater intensity during the onset than those of the pitch played.

Simulations
Then to the generation of noise by coarser structures existing in black hair: I have done some simulations to give you an idea how this might sound. In these simulations (an open violin G-string) noise is generated every time the string slips on the bow hair, or rather: random fluctuations from the programmed friction coefficient will occur during slips. In the output spectrum, this is primarily noticeable for frequencies *between* the harmonic frequencies of the played pitch. The coefficient deflections are given with normal distribution, and in the series below, their levels range from zero to ±100 % of the noiseless coefficient, in steps of 20%. In these simulations, partial slips across the bow-hair ribbon are ignored, but these should in principle only add more noise to the overall sound. To read about this partial-slip effect, I recommend Ref. 3, below.

My sound examples are given in three series, and can be played back from the page “Discussion”:

(1) White noise (flat spectrum); (2) Pink noise (–6 dB/oct); (3) Brown noise (–12 dB/oct).

Pink noise is the profile that matches empirical data the best.

Each series contains six examples with 0, 20, 40, 60, 80, and 100% noise, respectively, corresponding with increasing levels of hair/rosin coarseness. Notice that the bowing parameters are identical in all examples, but as the noise is gradually added, the onsets sound more and more sloppy.

There is a slight (ca 1 to 2 dB) raise in sound level when noise is added, but that concerns noise only: The simulations show that higher partials rather go down in amplitude, while the lower ones remain unchanged as long as the periodic stick-slip action is intact.

Knut

Ref. 3: R. Pitteroff and J. Woodhouse, "Mechanics of the contact area between a violin bow and a string (Part III Parameeter dependence)" Acta Acustica united with Acustica **84**(5), 929-946 (1998). http://www2.eng.cam.ac.uk/~jw12/JW%20PDFs/Pitteroff_3.pdf

Q: (Geo Kloppel)

Hi Knut, Thanks for the simulations. Now what do you think of the possibility that some bassists' preferences for dark colored rough textured hair are due to actually liking the noise? Perhaps they enjoy hearing the whole-instrument signature behind every note? I have numerous customers - even some violinists - who say the like "scratchy" hair, and of course some whose taste runs in the opposite direction - they want hair that's as noiseless as possible. Remember it sometimes turns out that the noise conceals surpassingly interesting phenomena. Think of the discovery of the cosmic background radiation! Best regards, -Geo Kloppel

A: (Knut Guettler)

I think we are approaching some quite important issues here now! Your choice of rosin/hair could very well be related to the quality of the instrument you are playing on; whether you would like to expose its signature or not. If you listen to above mentioned noise sound-example series, you will notice that the first three examples of each group sound increasingly scratchy, although the stick-slip action at the contact point is actually quite identical (with the same amount of nominal periods elapsing before Helmholtz occur). If your instrument is relatively benign (not “scratchy”) and possesses a nice signature, you may prefer a “noisy” hair-rosin combination—and vice versa.

However, the idea that the rosin/hair should have its *own* signature (apart from a spectral slope: white, pink, brown, etc.) must be rejected: Imagine that the hair had frictional surface irregularities distributed with a certain pace that gave the noise a spectral peak around the Bridge-Hill band, say 2000 to 3000 Hz. This addition of brilliance would have been quite attractive, right? No! – It

wouldn't! Such a spectral peak would have been shifted proportionally with bow speed, like a gramophone record played with variable rpm. You would have experienced a spectral shift down and up every time you made a bow change. I think it is to everybody's advantage that the frictional structure is quite smoothly distributed, giving a spectral *slope* rather than emphasizing certain frequencies.

Cheers!
Knut

C: (Geo Kloppel)

Excellent! Now I think we have perhaps salvaged some plausibility for the idea that choice of hair may have some real acoustical consequence after all, not in the bright spectral lines, but in what one wants (or does not want) to hear between them. This would go a good ways toward explaining why someone who plays several instruments might prefer rough scratchy hair on one but smooth hair on another, or even choose different hair for different performances on the same instrument..
-Geo