Quantifying the Properties of Your Sword

Advanced

If you want an objective evaluation of your sword you need to quantify its properties by *numbers*. As it turns out, you will need quite a few numbers. Some describe simple properties like the mass or length, some describe properties not so well known (like the moment of inertia). Some numbers are easy to get by simple measurements, others can't be measured directly and must be found by calculations or in some indirect experimental way. Worse, some desirable numbers may not be available at all, for example because you would need to take your sword apart in order to get then.
Here I will cover all properties of interest and describe the ways to obtain the respective numbers.
Let's start with the easy to get properties / numbers:

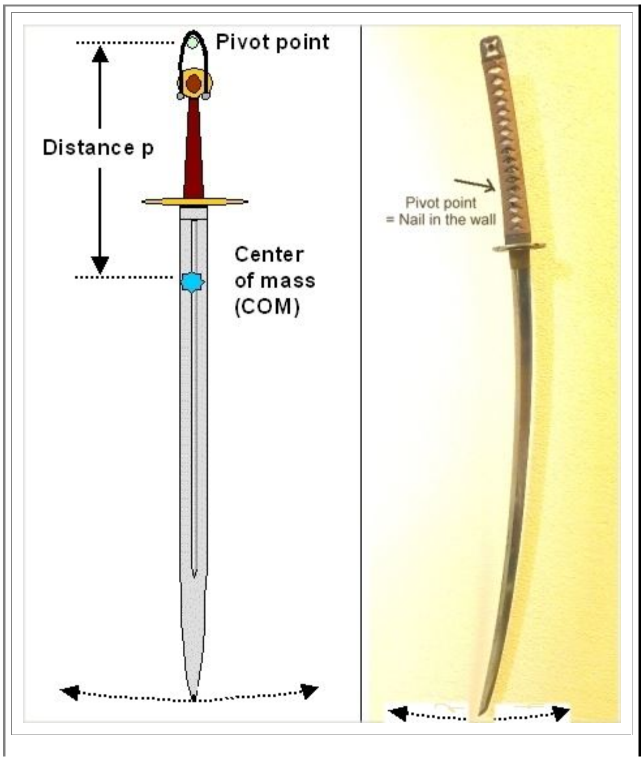
1. The ***mass*** of your sword and its parts.
If you have access to a halfway decent balance, you can weigh your sword. Always possible; can't be easier.
It might be more difficult or even impossible, however, to obtain the *mass of parts* since not all swords can be as easily disassembled as for example a katana. The mass of the pommel is of particular interest when it comes to fine-tuning the balance of a sword but that number might not be easy to obtain. If you cannot take off the pommel or other parts, I can't help you either. There is just no easy way to do that. Your best bet would be to calculate the mass from the volume and the density of the material used.

2. Everything relating to the ***geometry*** that can be measured by a ruler.
You can easily measure the length of the blade, its width and thickness, and so on. However, if the blade is tapered in any way, contains fullers, etc., just a few numbers will not describe the geometry in sufficient detail. The same goes for curved blades.
What does "sufficient detail" mean? That you could (in principle) compute the relevant properties as discussed here . That means that you can supply all data needed by the "Weapon Dynamics Computer" provided by Vincent Le Chevalier from his homepage.

3. Finding the ***center of mass*** (COM) comes next. I gave you two modules on that already - one in the backbone and one in the science section - so I won't say much here. The procedure can be a bit tricky for curved swords, in particular when the center of mass is actually *outside* the blade. Resting the back of the sword on your finger then will do the trick, but that only shows the "projection" of the true COM (in or below you finger) onto the sword. Be careful! It is a bit tricky to balance the sword, measure some distance on it, and write it down without dropping the sword. Could be dangerous! Do employ help here.

Now we come to your swords ***moment of inertia***, a key parameter. Neither easy to grasp nor easy to measure. Once more, I have dedicated already two modules to this topic, one in the backbone, one in the science section. Here I only need to stress that the moment of inertia of your sword is a number that *only* makes sense if given together with a *pivot point* or more precisely, the *rotation axis* running through the pivot point.

- How do me measure the moment of inertia with respect to some rotation axis? Well, by making the sword rotate around this axis. That is most easily done with a katana, just use a sturdy nail in the wall instead of the mekugi, the pin that holds the hilt to the blade as shown, or by "wiring" your sword somehow to a pivot point. The position of the pivot point doesn't matter (within reason), but you must know the precise distance ***p*** between the pivot point chosen and the center of mass.



Swing your sword!

- Now give your sword a push and let it swing back and forth like a pendulum. Measure the time T it takes for one full swing. Do it by measuring the time for 10 cycles or more and divide the time by the number of cycles - it's more precise. From that you get the frequency $\nu = 1/T$ or the cycle frequency $\omega = 2\pi\nu$.
  The moment of inertia I_A for the *axis chosen*, and the moment of inertia I_{COM} for the center of mass then come out as:

$$I_A = \frac{T^2 \cdot m \cdot g \cdot p}{4\pi^2} = \frac{m \cdot g \cdot p}{\omega^2}$$

$$I_{COM} = I_A - m \cdot p^2$$

- How you get that equation is shown in the science module. If you know the mass $m$and the distance p between the center of mass and the pivot point, you can now calculate the moment of inertia for *any* axis parallel to the one used, including the axis through the center of mass as shown. Just replace the distance p in the lower equation by the distance pivot point - new axis.

Let's move on to the ***percussion point***. Once more, two modules to this topic exist, one in the backbone, one in the science section. We need to know here that there isn't "a" percussion point but only a pivot point - percussion point *couple*. If we make the standard assumption that the pivot point is at the hilt close to the cross guard, the position of "the" percussion point then is somewhere down on the blade. It is this position we are after.

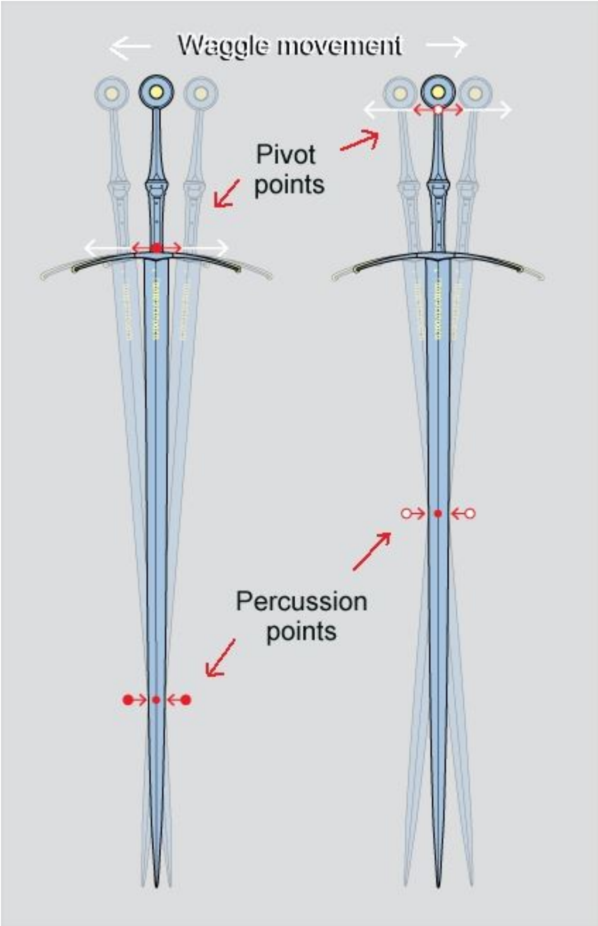
- The easiest way to obtain the percussion point is to calculate it. All you need to do is to find the moment of inertia I_{PP} for the pivot point close to the cross guard, which you do by using the relations given above. Then you determine the distance p_{PC} between the COM and the pivot point. The distance s_C between your cross guard pivot point and the percussion point is then given the following equation (derived in the science module).

$$s_C = \frac{I_{PP}}{m \cdot p_{PC}}$$

There are also two direct ways to find the percussions point of your sword: Hit something with it or make it waggle. The idea is to hit a piece of wood with the impact point moving up / down on the blade. You then will just *feel* when you reach the percussion point because then you feel "nothing" in your hand. Matt Easton of Schola Gladiatoria demonstrates that very nicely in his Youtube video mentioned elsewhere. Here is a screen shot:

Matt Easton finds the percussion point

- What you get is up to your sensitivity but if you feel it (or rather not feel it), you have the percussion point or at least that point that feels most comfortable for hitting something.
  Otherwise go for the waggle test. Hold your sword loosely around the pivot point and move it quickly back and forth. The sword then moves as shown below. If you look at the pictures here , it is obvious why. It takes a bit of practicing and the precise location is not all that easy to see. You do get a clear impression about the approximate position, however.



The "waggle" test for finding the percussion point

Source: From Vincent Le Chevalier's homepage [1)]
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- It remains to find the position of the ***vibration nodes***. However, I have nothing to add to what I already presented in the main part.