Sword measurement protocol

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Object

The purpose of this document is to provide a step by step protocol for the measurement of swords. The goal is to obtain sharable, reproducible and complete measurements of the functional aspects of swords, in particular in terms of mass distribution, which determines their reactions to applied forces. These measurements can afterwards serve as input to tools such as the Weapon Dynamics Computer[1], and produce visual illustrations such as the one displayed in the catalogue of the exhibit The Sword – Form and Thought in Solingen[2]. This document does not go into details about the physical interpretation of the measurements, or the physics behind them. The interested reader should either consult the previously cited book, or navigate to its companion page[3].

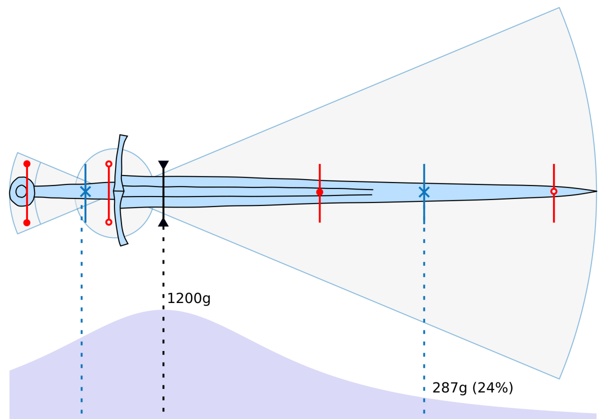

Figure 1: An example of the visual display of dynamic properties. See the catalogue The Sword – Form and Thought for more details.

This protocol is designed to be applicable to any straight or slightly curved sword, modern or antique. It is best to follow the whole protocol, although some of the parts may have to be given up on the most fragile specimens. When applicable, the constraints in terms of manipulation are summed up before each part.

A measuring sheet is attached in the last section of this document[4]. It is intended to make it easier to take notes when measuring a sword. It can be completed by free-form notes and sketches, if needed and possible. Although the measurements could be taken in a variety of units, it is advisable to use the metric system for easier communication.

A trained person can obtain the basic essential measurements (marked with a '*' hereafter) in less than 10 minutes. More time may be needed for a more complete dataset, of course.

At all times when swords are manipulated it is best to do so with proper gloves, and to always exercise good caution in order to avoid accidents and preserve both the objects from falls or shocks, and the person from cuts or stabs. Naturally museum examples should be handled even more carefully.

1 https://subcaelo.net/ensis/dynamics-computer/
2 The Sword – Form and Thought, ed. Barbara Grotkamp-Schepers, Isabell Immel, Peter Johnsson, Sixt Wetzler, Solingen: Deutches Klingenmuseum, 2015

3 https://blog.subcaelo.net/ensis/documenting-dynamics-of-swords/
4 A standalone version of the measuring sheet is accessible here: https://subcaelo.net/ensis/measurementProtocol/measureSheet.pdf

Qualitative data

Sword identification *

Very light or no manipulation

The sword should be identified as precisely and uniquely as possible. For modern examples, maker, year of production, model name or number should be used. For museum specimens, museum number or tag are ordinarily unique identifiers. It can be useful to supplement this accurate identification with a less formal one for communication purposes.

For antiques, the datation of the sword, or that of its parts, should be noted.

The sword's typology should be noted. There are several well-accepted typologies: Geibig, Petersen, Oakeshott (supplemented by Elmslie for messers and falchions), Norman... A sword's type often has functional implications.

Some swords are composite, assembled in their current state much later than the individual parts were built. A number of rapiers are particularly notable for this. Any observation or element of the item's history indicating or ruling out a composite have to be carefully noted, as this can have a great incidence on the significance of the specimen for a functional study.

Photographic documentation

Very light or no manipulation

If possible, photographs should be taken.

At least two full-length shots, one for either side, serve as reminders of the general shape and type. In these a tape ruler should be present along the length of the sword to account for lens distortion. Close-up shots of any pertinent details should be taken. The hilt is especially important; complex hilts should be taken from several angles.

The photographic data cannot replace the quantitative measurements below. Rather, it should be used to document the complexities of shapes, surface states etc.

Competent operators can replace the photographic documentation by full-scale sketches of all relevant elements.

Quantitative data

Axis and longitudinal points *

Very light manipulation

The longitudinal axis of a straight sword is the line which runs from pommel to tip in the middle of the blade. Locations on the sword are positioned along this axis by their signed distance from a common reference point, discussed in the next paragraph. A tape ruler is the appropriate tool to measure position on the longitudinal axis, measuring to the nearest millimeter is generally sufficient. The principle of recording locations on the sword by the signed distance from the reference will be used throughout the whole protocol.

The reference point should be chosen at a location that is easy to measure from. The tip of the blade works well on many swords, as long as the hilt is not closed. Otherwise the hilt itself can be used, for example the outer surface of the cup on a taza rapier, taking its thickness into account to measure on either side. The reference point has no functional incidence by itself, but should be noted for informational purposes.

Several locations are essential to the study of the function of the sword (see figure 2):

- Hilt extremity: the extremity of the sword on the hilt side. This location might disregard any peening nut: that part is not reliable, sensitive to modification, and often not essential to the design of the sword. However, when in doubt, include all the parts.
- Grip back: the aft gripping position on the hilt. On the classical cruciform sword, this is just between the pommel and handle (or tang if the handle is not preserved). On some swords there is no pommel, that point is then congruent with hilt extremity. On others, the handle flows seamlessly into the pommel; in these cases it is often the narrowest point on the grip that gives the best definition. This point might coincide with the end of the handle, but not always so. Any unclear case such as this should be the object of a note and optionally sketch to clarify the assumed location.
- Grip front: The forward gripping position on the hilt, closer to the blade. This should be taken at the junction between cross and handle, which provides an accurate, unambiguous location on the vast majority of swords. Sometimes a quillon block can be present; in this case, the grip front should be taken at the quillons, not at the block, as it is the position that is functionally meaningful.
- Blade extremity: the tip of the weapon. This is nearly always well defined; however some weapons might have slightly damaged tips. In that case the current tip location should be used, but the supposed location of the undamaged tip could be noted separately.

In general, and especially on curved swords, the axis should be picked as the line joining the two primary vibration nodes (see Flexible body properties below). A slight imprecision in axis location usually does not matter. If desired, the locations on the sword can be noted in two dimensions, as the distance from the reference point along the axis, and as the distance from the axis.

In the most difficult cases, again especially on curved swords, it is advisable to use a large sheet of paper with the axis drawn over it, lay the sword on it and report all the points of interest on the paper. The measurements can then be taken on the sheet, which is always more convenient. Care must be taken to lay the sword back on the sheet exactly at the same place after any manipulation. A good solution for this is to mark a pair or more of the points of contact between sword and paper.

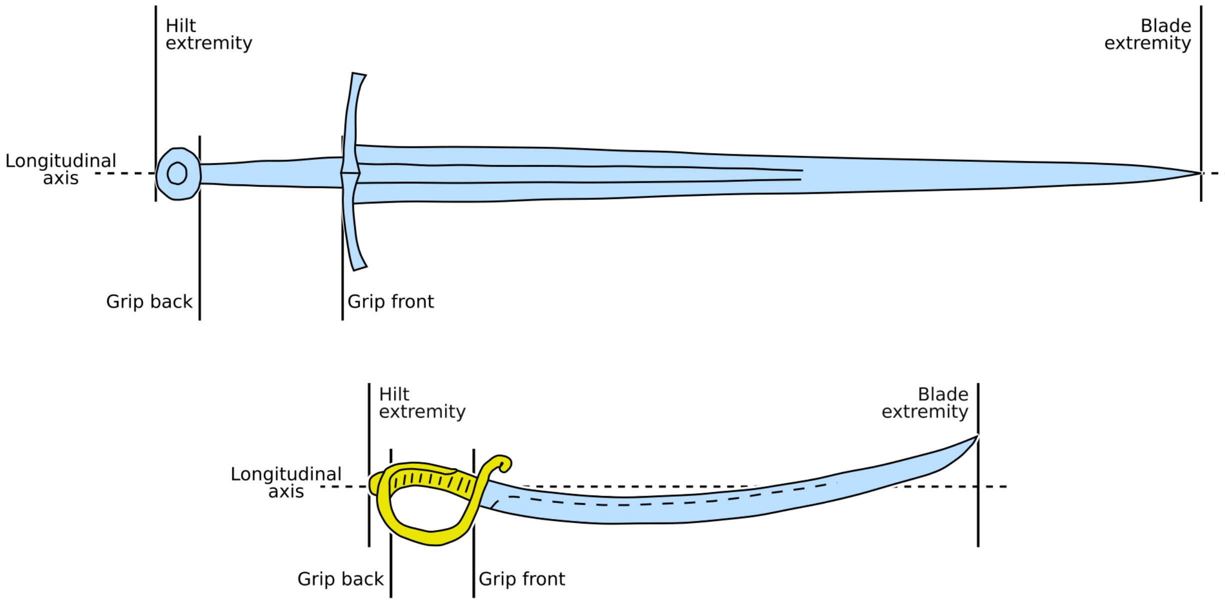

Figure 2: Defining the longitudinal axis and the essential points on a longsword and a saber

Physical measurements

Mass *

Light manipulation

Mass can be easily and accurately measured on a kitchen scales. These generally have the proper range and precision for the mass of swords, which is approximately 0-5kg±1g.

Care must be taken to be able to rest the full weight of the sword on the scales. Ideally, some sort of support should be used so that no parts of the sword interfere with the table or need to be supported by the hand. A high and wide dish bowl works well in this application. In the case where no suitable support is available, the best method is to rest the sword vertically on its pommel and just use the hand to ensure the best possible verticality, without pressing or lifting the object of course.

Center of gravity *

Light manipulation, static suspension by a string

The center of gravity is located on the longitudinal axis. To determine its position the best method is to pass the blade horizontally through a loose loop of string, lift the sword up, and adjust the position of the loop until the sword is in horizontal equilibrium resting only on the string. The sword can then be put back down, taking care not to move the loop, and the position measured from the reference point. The loop serves as an index to the measured position, which is often useful because the center of gravity is generally located on the blade, which may not offer distinctive features to memorize the location. On straight swords it is easiest to do this with the flat of the blade facing up, on curved swords, because the center of gravity can be outside the blade, with the convex edge (ordinarily the true edge) facing up.

Radius of Gyration

The radius of gyration is a measure of how spread the mass is around the center of gravity, and is a key parameter of the dynamic behaviour of the sword. It is difficult to measure and can only be accessed indirectly by observing the sword in motion. The Weapon Dynamics Computer provides two methods to estimate it, but it is best to store the basic measurements themselves. The first method is low-gear but less accurate, and some operator training is necessary. It is helpful to have the computer at hand to check the consistency of the measurements as the swords are measured; when errors are spotted as the measurements are done, the process may be started again or the results checked as long as one still has access to the sword.

*Waggle tests **

Dynamic manipulation, always held by hand

A waggle test is performed by hand and eye only.

The principle is to pick an Action point, normally somewhere on the hilt, where you pinch the sword as precisely as possible, letting the sword hang freely vertically tip down towards the ground. Then, you impose a horizontal back and forth motion to the action point. This will cause the sword to apparently move around a fixed point somewhere down the blade, called the Pivot point associated to that Action point (see figure 3). By measuring several such pairs, the radius of gyration can be estimated.

Both points must be noted for each pair, as the location of the pivot point depends directly on the location of the action point.

The motion on the action point does not need to be wide, but it needs to be as quick as possible. The higher the frequency of oscillation, the further the fixed point will be seen down the blade. At a high frequency it converges to the pivot point.

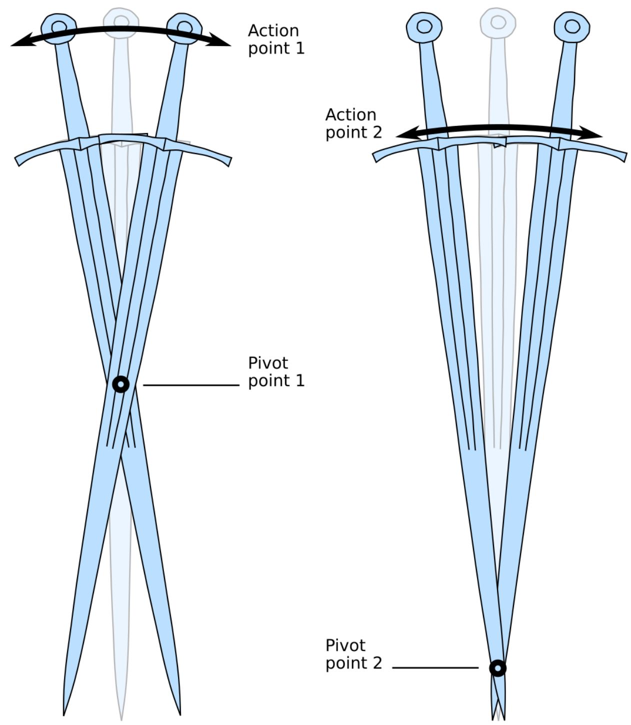

Figure 3: Two waggle tests.

Care must be taken to apply as little torque as possible to the sword at the pinching point. The grip must be only as tight as needed not to let go of the sword. This constraint must be taken into account when choosing an action point, as not all locations on the sword lend themselves to this.

In order to spot and mark the fixed point on the blade, a hair tie can be used. It is looped around the blade and moved as needed until it marks the pivot point.

While only one pair of action / pivot points is necessary, in practice two or more are better as it allows for consistency checks and an estimation of error.

Pendulum tests

Dynamic manipulation, suspended to dedicated device

A pendulum test is more accurate but needs special apparatus to be performed in good conditions (depicted in figure 4). A thorough description of a tested setup is accessible in a blog post[5]. This makes it possible to suspend the sword safely by wires and constrain its oscillation to achieve precision without undue risk to the object.

The basic idea is to suspend the sword as a pendulum at a chosen Pivot point, and measure the period of oscillation. The period is ordinarily quite short and must be determined precisely, therefore it is recommended to time a given number of oscillations instead; ten to twenty is sufficient.

Similar to the waggle test, several Pivot points can be used to increase the confidence in the results.

Figure 4: The pendulum setup

Flexible body properties

Swords are not completely rigid and have some flexibility especially in the flat-to-flat plane. Measuring these properties requires the sword to be lightly bent and this should only be done on specimen that are deemed in a good enough state.

*Vibration nodes **

Light impact making the sword vibrate

Flex and mass distribution interact to define two primary vibration nodes, one located on the blade and the other on the hilt (figure 5). These nodes seem to be intentionally placed on swords.

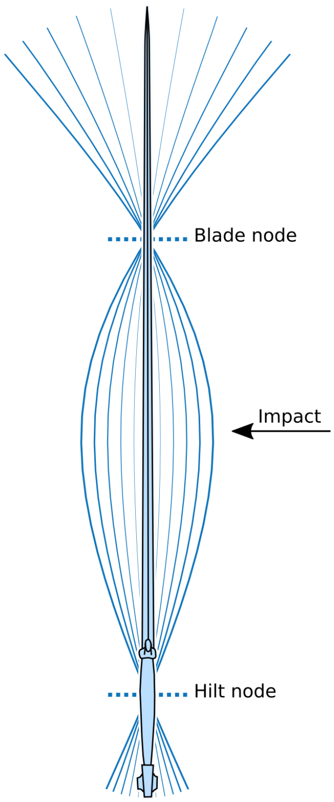

Figure 5: The primary vibration nodes appearing upon impact. The amplitude of vibrations has been exaggerated for legibility

The blade node is the easiest to spot. The blade must be held vertically, with a relaxed grip, looking at the edge, and tapped lightly with the hand on the flat. The blade will vibrate but one point will remain steady, it is the blade node. Note its location along the longitudinal axis. Again a hair tie is useful to mark the location. If much vibration is felt in the hand, it might be necessary to adjust the gripping point.

If the sword is so stiff that it does not visually vibrate, the node can be sometimes be found by tapping at different locations, until the one that causes the shortest, highest pitch vibration is reached.

The hilt node is more difficult to precisely measure because the hilt inherently vibrates less, and is thicker than the blade. When looking for it, the best method is to hold the sword by pinching it at the blade node, and tap the blade again. The steady hilt node will appear most clearly in this way. Once it is located it can be held to look for the blade node with more precision.

5 http://blog.subcaelo.net/ensis/measuring-swords-pendulums/

The sequence for the most accurate measurement is therefore:

a) Grab lightly the hilt, find the blade node
b) Pinch at the blade node, find the hilt node
c) Pinch at the hilt node, re-determine the blade node

But it is often quite difficult to grip precisely at the hilt node, thus the third step is rarely possible or useful except in the most special cases, when the initial grabbing position on the hilt was far from the hilt node. For the same reason it is useless to iterate further than these three steps.

Flexibility

Blade flexion under heavy force on tip

Quantifying flexibility and its variation along the blade is somewhat hard, and a standardized, reproducible, accurate and low-stress method is yet to be designed.

The most widespread method so far known to the author has been pioneered by training sword maker Black Fencer[6]. The sword is stood vertically with the tip on the scales, then pressure is applied until the blade flexes. The value read on the scales at that time is the flexibility in kg.

That method is only adapted to training swords, or specimens that can cope with a lot of pressure on the tip: the common values on flexible steel training swords are between 5kg and 20kg[7].

Section profile

Light manipulation

It can be informative to measure the blade profile at several points along the longitudinal axis. The blade profile is defined by width, thickness and cross-section shape. Ideally all the changes in profile would be documented. The ricasso, when present, can also be documented here.

Width and thickness are measured with calipers.

There can be a lot of variety in cross-sections. There are common forms: square, diamond, lenticular, hexagonal, which can be fullered or hollow-ground. The best documentation remains a sketch with all the relevant dimensions.

Some hilt details can also be documented in this section, for example handle width and thickness at various points, and potentially overall pommel dimensions. A complete documentation of pommel shape, which is often very complex in 3D, needs several sketches and belongs to the next section.

6 https://blackfencer.com/en/content/18-flexibility-measurement
7 https://www.keithfarrell.net/blog/2017/03/safe-training-swords-part-2-measuring-flexibility/

Hilt details

Light manipulation

Several additional hilt details can be measured. This section is left to the free-form notes on the measuring sheet because it depends heavily on the type of hilt and specificity of the particular specimen. The deeper into details one gets, the hardest it is to ensure unambiguity and reproducibility (see figure 6). When defining any non-standard measurement, it is best to keep the functional aspects in mind.

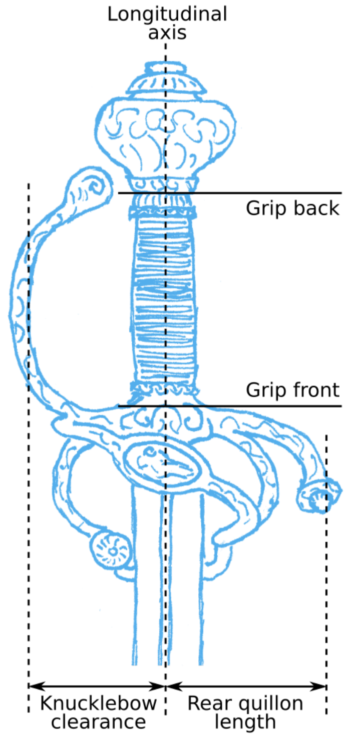

Figure 6: Hilt details on a complex hilt (sketched from Wallace Collection A623)

Quillon length and thickness have a functional impact. For curved quillons, total distance from the axis is the pertinent measurement, ideally disregarding the thicknesses of knobs and other such decorative features. As before, thicknesses are best measured with calipers, width or length can be done with a tape ruler. Sword hilts are often slightly asymmetric, so that it can be necessary to distinguish front and back quillons.

When a knucklebow is present, its clearance from the handle can be interesting to note. For cup hilts, the size of the cup, in three dimensions if it is not spherical, can be noted as well. Complex hilts defined by bars can sometimes be approximated by a cup equivalent.

Some types of swords have lugs or hooks on the blade forming a sort of secondary cross. This can be documented in this section as well.

Measuring sheet

Name	
Type	

Reference			
Hilt Extremity		Blade Extremity	
Grip Back		Grip Front	
Mass		Center of Gravity	
Hilt Node		Blade Node	
Flexibility			

Waggle tests *Pendulum tests*

Action point	Pivot point	Pivot point	Period x

Section profile

Location	Thickness	Width	Cross-section

Notes	