5.5 Elementary Pickup Parameters

The market offers a large number of different magnetic pickups which differ in basic construction, in their dimensions and in the transmission behavior. Some of the electric parameters can be measured easily – these are therefore often listed in overview tables and connected to sound attributes such as: brilliant, muffled, loud. Of course, the pickup in itself does not generate a sound – that requires a vibrating string, an amplifier and a loudspeaker. In fact, the sound attributes are absolute, categorical judgments, although they are meant as comparing, ordinal judgments: calling a pickup "loud" actually reads: "louder than most others". "Shrill" therefore stands for "this pickup generates – using a customary guitar connected to a customary amplifier with a customary control setting – a sound with much more treble-emphasis than most others". What then causes a pickup to sound louder or shriller than others?

5.5.1 DC resistance

The **DC resistance** is seemingly the most important parameter. It can be determined very easily with an Ohm-meter. Sometimes alternatively the term '**impedance**' is used, other times the term 'loudness '. The former use is not actually wrong since it is possible to connect DC to an impedance – the frequency should, however, be specified. In other words, one should either talk about 'impedance at 0 Hz', or simply of 'DC-resistance'. Statements like 'loudness = 8 kOhm' or 'Output = 8 K' are plain incorrect. For one, the quantity and the unit are already a mismatch, and even more importantly there is no simple connection between loudness and DC resistance. This is easily seen when taking the magnet out of the pickup: the DC-resistance remains the same, but the loudness approaches zero fast.

The DC-resistance R is determined by the specific resistance ρ of the coil wire, the area S_{Cu} of the wire cross-section, and the length l of the wire: $R = l\rho / S_{Cu}$. **Copper wire** is almost always the chosen material for magnetic pickups, for it we get: $\rho \approx 0.018\ \Omega\text{mm}^2/\text{m}$. Depending on additions and impurities there will be small variations in ρ while larger variations should be expected on the wire diameter. More recent data sheets specify AWG-42-wire with a diameter tolerance (due to manufacturing processes) of ±5% an. Since the cross-sectional area and the diameter have a quadratic interdependence, that cross-sectional area S_{Cu} and thus the resistance value R has a spread of ±10%.

The **diameter** D is very small – often as thin as approx. 63 μm and thus thinner than a human hair.
US-literature specifies the diameter as **AWG** (American Wire Gauge) an. AWG-42 – a wire very often used in pickups – has a copper diameter of 2,5 mil = 63,34 μm. The following approximation can be used for conversions in the range 30 < AWG < 50:

$$D_{Cu} = 10^{0{,}902 - AWG/20}\,\text{mm}^{\clubsuit} \qquad \text{e.g.: AWG-42} \rightarrow D_{\text{Cu}} = 63.3\ \mu\text{m}$$

The nominal value of the resistance per meter for this wire (AWG-42) is: **5,4 Ohm/Meter**.
Manufacturing variations lead to a scatter of 4,9 to 5,9 Ohm/Meter (modern manufacturing).
It also depends on the temperature: R rises per °C by 0,39 %.

♣ more precisely: $D = 0.127\text{mm} \cdot 92^{(36-AWG)/39}$

A thin **layer of varnish** applied to the cylindrical copper wire serves as insulator. As a consequence, the diameter grows by 10% for a *single build* wire (one coat of insulation) and for a *heavy build* wire (2 coats of insulation) by 20%. Since merely very tiny voltages are generated in pickups, one coat of insulation is sufficient.

The maximum applicable length of wire depends – other than on the wire diameter – on the winding space on the coil bobbin and on the fill factor. Winding by hand results in the wire of individual turns crossing the wire of other turns, and more air and less copper is in the coil. Exactly positioning every turn next to the other is achieved via winding by machine; the fill factor is higher. The **pull** has next to no influence: in order to firmly layer the turns, a small braking force is applied. However, since such delicate wire breaks very easily, there is not much margin here. One manufacturer recommends winding AWG-42-wire with approx. 0,33 N pull. The strain in this case is only about 0,1% and the transversal contraction even less. Any resistance increase due to the pull is therefore negligible.

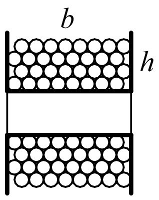
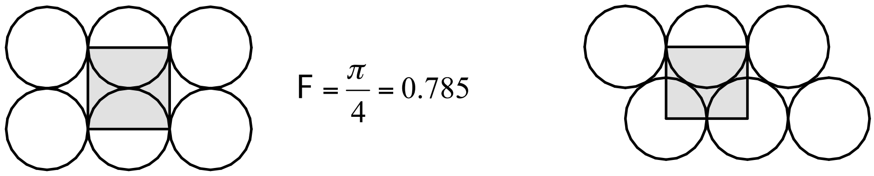


Fig. 5.5.1: Cross-section through a pickup coil. Winding width *b* and winding height *h* define the interior dimensions of the bobbin. The wire diameter is shown drastically enlarged.

Fig. 5.5.1 shows the cross-section through a pickup coil. For customary pickups the width *b* varies between 4 – 12 mm and the height *h* between 5 – 15 mm; very small coils (e.g. Gretsch) have a height of merely approx. 2.5 mm. Often the available winding area $S = b \times h$ is between 30 und 60 mm^2. For an AWG-42-wire the cross-sectional area including the varnish is approx. 0.004 mm^2. To calculate the largest possible number of turns from these data we need to estimate the proportion of air in the winding. **Fig. 5.5.2** presents two ideal cases: the **fill factor** F is the quotient of circular wire-area to rectangular winding area.

The right-hand section of Fig. 5.2.2 shows the desirable objective: all turns fit tightly into the notch between the wires below and the fill factor is in excess of 90%. A winding of such precision is only achievable with a correspondingly precise feed rate control. Given that the feed is merely 71 µm per turn, only smaller fill factors will be achievable in practice (F = 70 – 85%). The Stratocaster pickup, for example, offers a winding area of approx. 40 mm^2. The application of 7600 turns (a usual value for CBS-Fender in the 1960s) results in 30 mm^2 wire area and approx. 75% fill factor. Given an average length of 14 cm per single winding turn the overall wire length comes to 1064 m which can be calculated to a DC resistance of 5.7 kΩ. This value is quite nicely confirmed with measurements.



$$F = \frac{\pi}{4} = 0.785 \qquad F = \frac{\pi}{2\sqrt{3}} = 0.907$$

Fig. 5.5.2: Fill factor F for ideal wire positioning. The cross-section of the copper itself is – for a wire with a single layer of varnish – approx. 80% of the full wire cross-section area; for a double layer of varnish approx. 70%. Depending on manufacturer, insulation type and manufacturing method other values may result!