3.3.2 Skin effect in steel strings

As a string moves within the magnetic field of a pickup, its position relative to the pickup magnet changes. As a consequence, field strength and flux density within the string also change. A variation in the flux density will induce, in the electrically conductive string, an eddy current (**Fig. 3.5**), that itself generates its own magnetic field in opposite direction to the primary field. Because the strength of the eddy current depends on the *change* of the primary field, the primary field is more and more squeezed out of the string as the frequency increases. At high frequencies, a substantial magnetic flux is left merely in a thin outer layer (i.e. the skin) of the string. Therefore, the magnetic conductivity decreases with increasing frequency. This so-called skin effect is dependent on the basic magnetic conductivity of the material (a large μ results in a large *B*), and on the electrical conductivity (a large σ results in a large *I*). An extensive discussion of the skin effect will follow in Chapter 4.10.4.

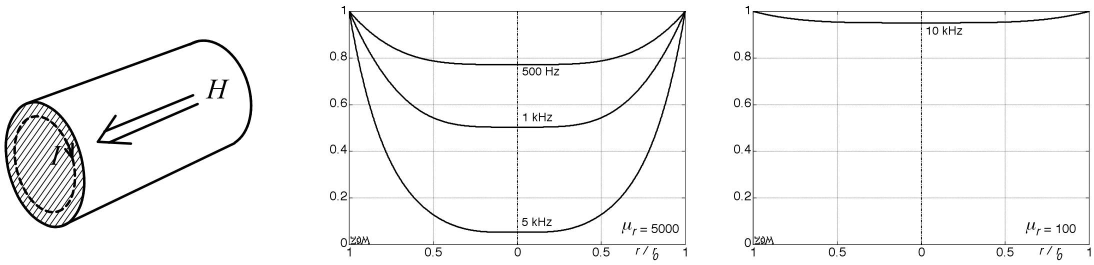

Fig. 3.5: Metal cylinder permeated axially by the magnetic field *H*, with eddy current *I* (left); radial distribution of the magnetic flux density in a 17-mil-string (middle). For μ_r = 100 (right), there is almost no field distribution: the magnetic flux density is practically independent of the location. Approximation: μ_r is constant.

Given a sinusoidal vibration, the temporal change of the flux density is particularly strong at the zero-crossing. At these instants, the magnetic field will therefore not be able to permeate the complete string material – there will be delay in the build up of the field. In the left-hand-section of **Fig. 3.6**, the hysteresis loop measured at 1 Hz is depicted; on the right we see the broadening at increased frequency. The skin effect is relevant if the whole hysteresis reaching into saturation is measured. Given the string vibrating over a pickup magnet, we find other conditions, though: within the string there is a strong DC-field with a rather small change superimposed. In this case it is not the differential permeability that is important, but the reversible permeability, the latter being much smaller in steel string than the differential permeability (μ_{rev} < 70, Chapter. 3.3.3).

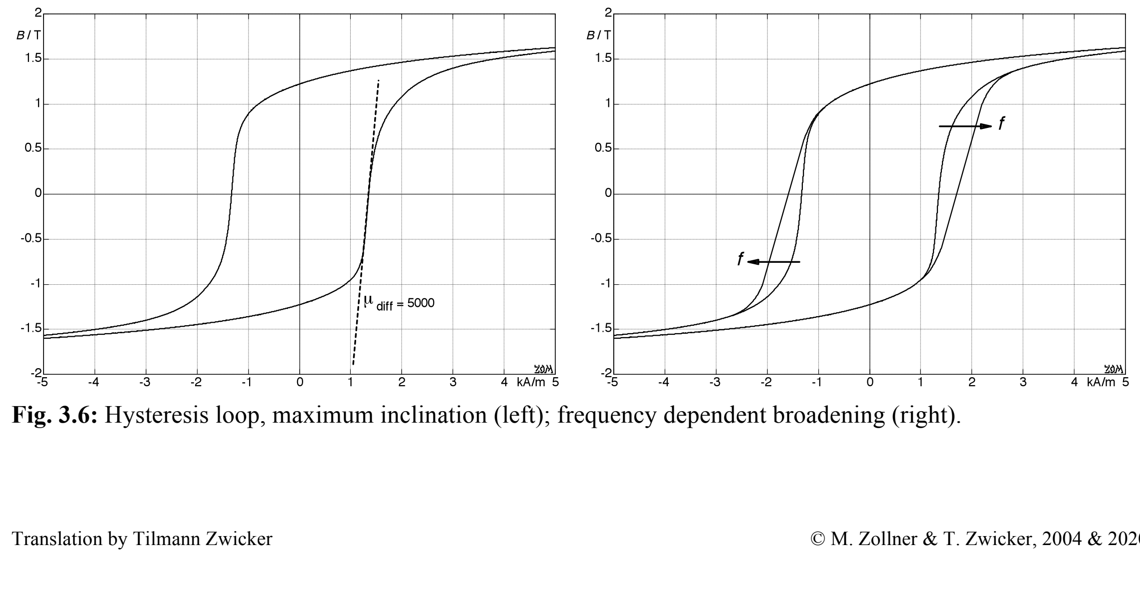

Fig. 3.6: Hysteresis loop, maximum inclination (left); frequency dependent broadening (right).