3.2.9 Permeability as a function of frequency

If the permeability of a ferromagnetic or ferrimagnetic material be measured, then the following holds for laminated cores, dust cores, and ferrites: at low frequencies, μ is almost independent of frequency. However, for each type of material, there is a critical frequency above which the permeability falls. This critical frequency is reached at a lower value for high-permeability materials than for materials of lower permeability. Again, among sheets of various thicknesses, the thicker the sheet, the earlier the fall-off.

For sheet and strip, the initial permeability falls off, above the critical frequency, as $1/\sqrt{f}$. Figure 3.41 shows the shape of a typical permeability–frequency curve, according to a calculation by Kornetzki[87], for various kinds of sheets whose initial permeability lies between $300\mu_0$ and $100\,000\mu_0$.

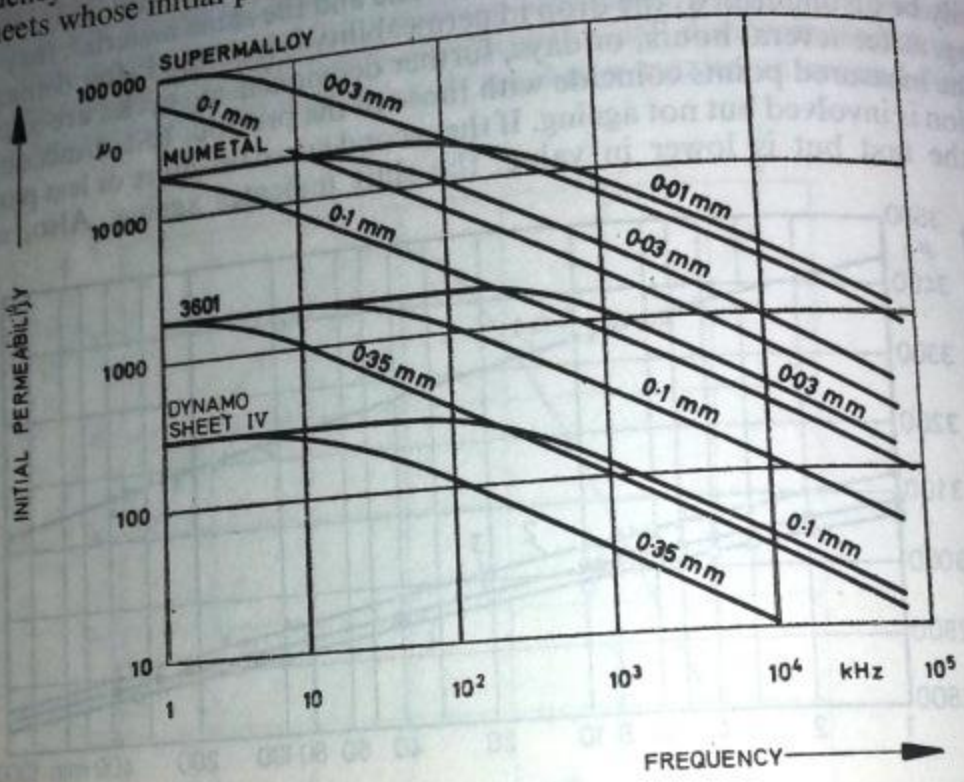

Figure 3.41. Initial permeability of laminated cores as a function of frequency[87]

The critical frequency f_{cr} is almost wholly determined by eddy-current losses; it can be calculated from the formula

$$f_{cr} = \frac{4\varrho}{\pi\mu_i D^2} \tag{3.72}$$

in which ϱ stands for the specific electrical resistance of the sheet, D its thickness, and μ_i the initial permeability. Actually the drop is, in general, steeper than that shown in the figure; there are several reasons for this, such as the absence of insulation between individual laminae, inhomogeneity of the material, and relaxation effects. There are basically two ways of raising the critical frequency: either the specific electrical resistance ϱ must be increased, or the sheet thickness D must be reduced.

Now it has already been mentioned that ferrites have a specific electrical resistance greater than that of metallic materials by several orders of magnitude. One might therefore expect that their permeability would remain constant up to an arbitrarily high frequency, but this is not so. As Figure 3.42, taken from the same investigation by Kornetzki, shows, these materials also exhibit limiting frequencies above which the permeability falls. As for sheet material, the permeability remains constant up to higher frequencies the smaller the value of μ. Above the critical frequency, μ falls as $1/f$.