# Using change of permeability

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Recent interest has been shown in using materials that exhibit a change of magnetic permeability, or more precisely a change of *incremental* permeability, as a means for obtaining over-unity operation. The argument is quite simple, if you charge an inductor that has a low permeability core, then discharge the inductor at a higher incremental permeability, you go round a BH loop clockwise. The area of that clockwise loop represents excess energy (actually energy-density) that is recovered electrically. That energy comes from the mechanism that increased the permeability, e.g. if the effective permeability were increased by closing an air gap in the core, the changing flux would induce voltage so as to draw more energy from the input, and that explains the excess energy. If there are material characteristics where such an increase in incremental permeability occurs without a consequential flux change, then we have a means for harvesting energy supplied by Nature. A magnetic resonance such as domain-wall resonance is known to produce such a characteristic.

**Modelling Permeability.**

The magnetization within hard materials is often modelled by using the surface or solenoidal current equivalent. Effectively the magnet is represented by an *air-cored* solenoid of equivalent dimensions, the solenoid carries a current that creates a magnetic field equivalent to that of the magnet. That surface current is the aggregate effect of all the atomic current circulations (dipoles) within the material. To the author's knowledge magnetically soft materials have never been modelled in the same way, yet soft materials also get their characteristics from atomic dipoles. This new approach turns out to be very simple to accomplish. The atomic dipoles supply an H value that is $\chi$ times that supplied by the coil current, where $\chi$ is the magnetic susceptibility of the core material. Thus the core (now modelled as an *air-core*) receives the sum of $H_{applied} + \chi H_{applied}$, as shown in Figure 1.

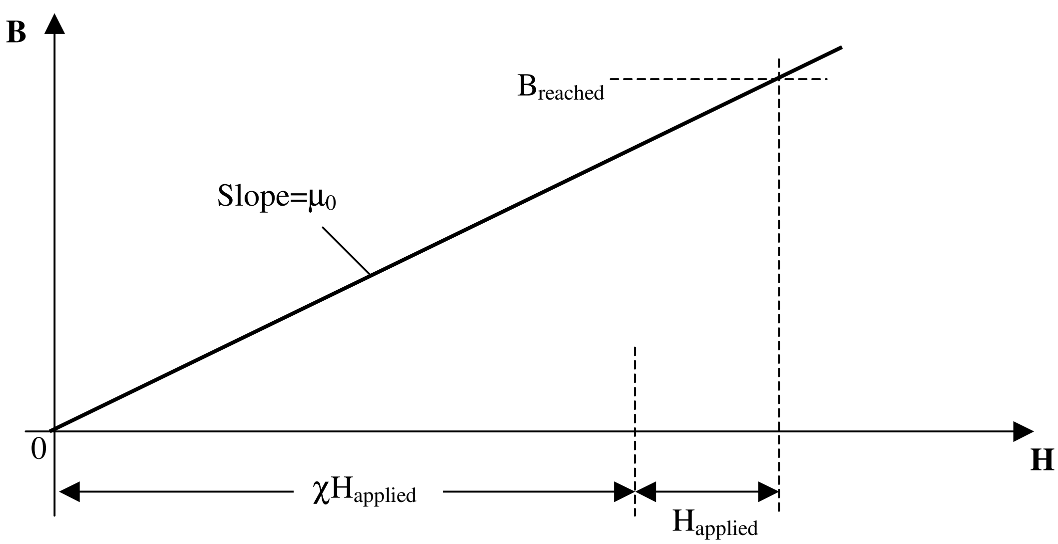


**Figure 1.**

From the usual perspective where the atomic contribution to H is ignored, this graph is drawn with the zero H axis moved as shown in Figure 2.

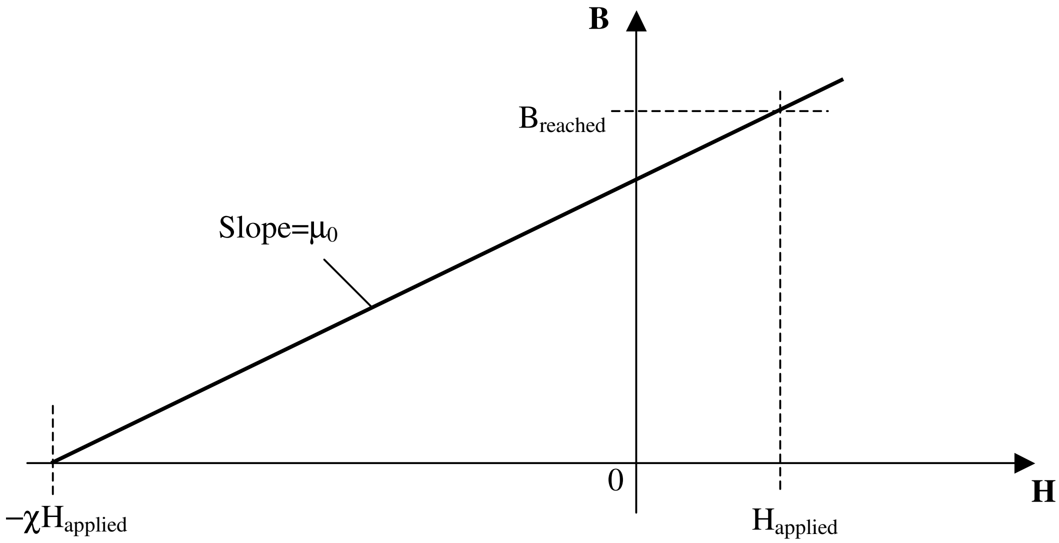


**Figure2**

In this graph $\chi H_{applied}$ is shown as negative, but this is just for presentational purposes and also to demonstrate the similarity to the modelling for permanent magnets. The total H applied to the *air-space* within the material is $\chi H_{applied} + H_{applied}$ which results in B reaching the value shown. From the perspective where $\chi H_{applied}$ is invisible, the ratio of $B_{reached}$ to $H_{applied}$ has the slope $(1+\chi)\mu_0$ as shown by the red line in Figure 3. Of course $(1+\chi)$ is the relative permeability $\mu_R$.

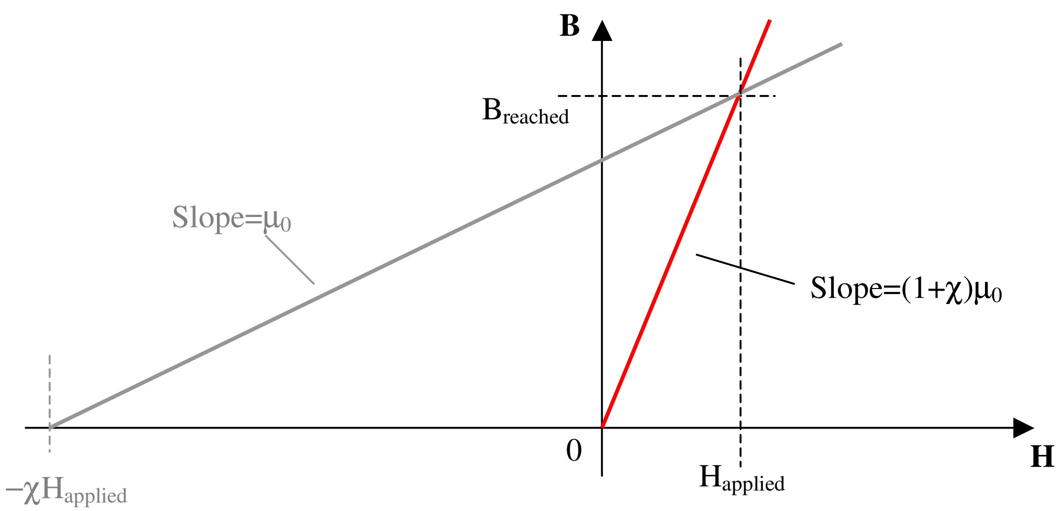


**Figure 3**

Converting Figure 3 into flux v. mmf simply involves geometric multiplying factors, mmf=H*l* where *l* is the core magnetic length and flux=BA where A is the core area. We then arrive at Figure 4.

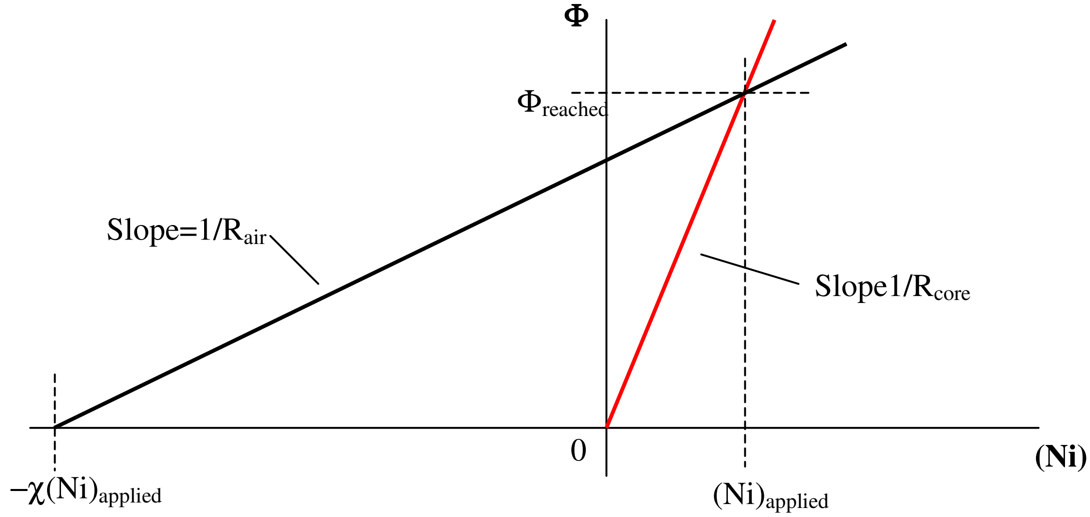


**Figure 4**

It can be seen that the normal magnetic circuit where the applied (Ni) ampere turns drives flux through the core reluctance $R_{core}$ can be replaced by a new circuit where $(1+\chi)$(Ni) drives the same flux through the reluctance $R_{air}$ of the *air-space* occupied by the core.

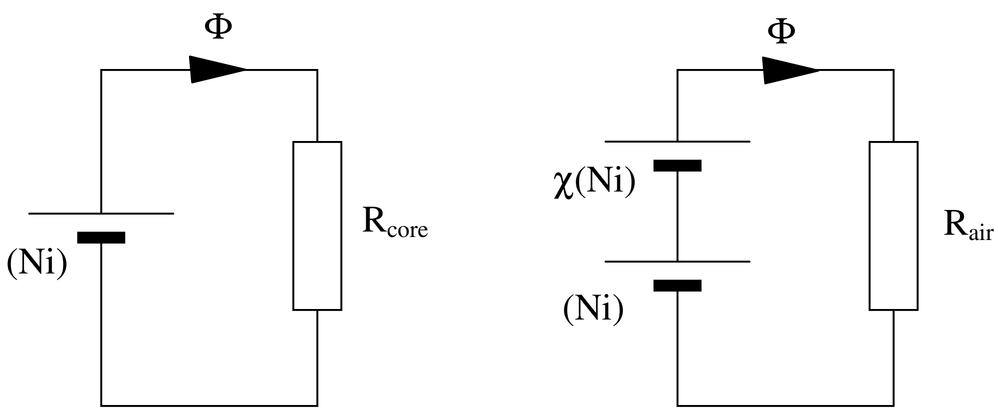


**Figure 5**

The reluctance $R_{core}$ is given by

$$R_{core} = \frac{l}{\mu_R \mu_0 A}$$

whereas the reluctance of the *air-space* occupied by the core is

$$R_{air} = \frac{l}{\mu_0 A} = \mu_R R_{core}$$

Of interest here is the magnetic energy $\frac{\Phi^2 R_{air}}{2}$ stored in that air space, which quite clearly is much greater than the conventional $\frac{\Phi^2 R_{core}}{2}$ stored in the core. The former is energy stored in the magnetic fields existing between atoms or molecules that is not normally accessible.

If we now model the susceptibility as having a resonance we have to consider incremental permeability which we can do by giving the applied Ni value in figure 4 a small AC variation, with the achieved $-\chi(\mathrm{Ni})_{\mathrm{applied}}$ receiving a greater variation, as shown in figure 5.

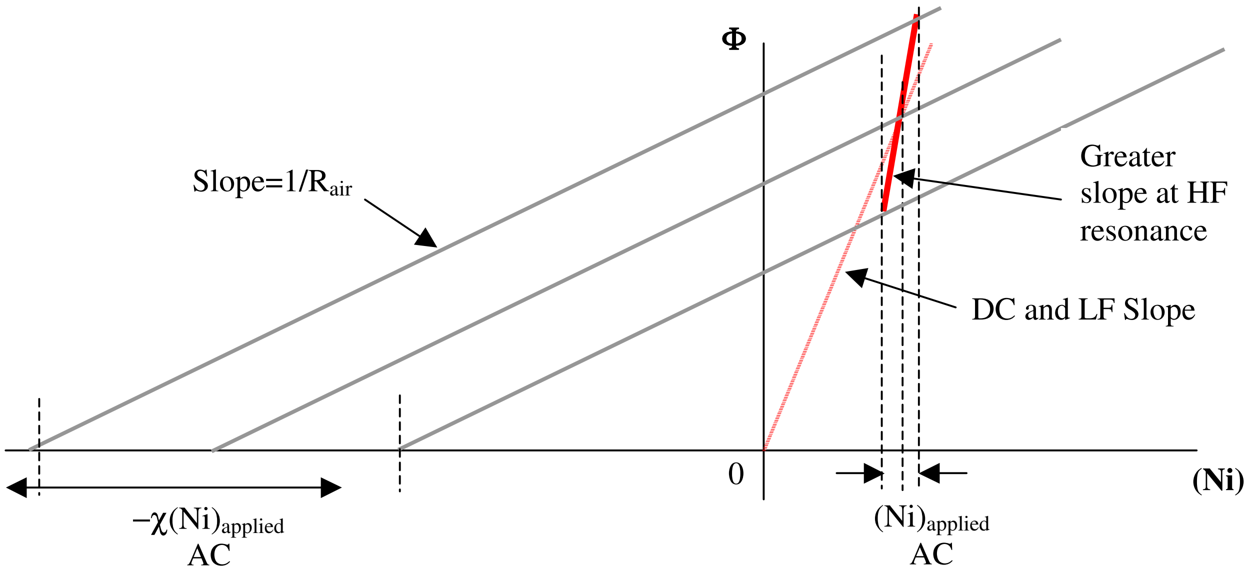


**Figure 5. Showing the effect of resonant $\chi$**

We can now look at charging an inductor at low frequency and discharging it at the $\chi$ resonance.

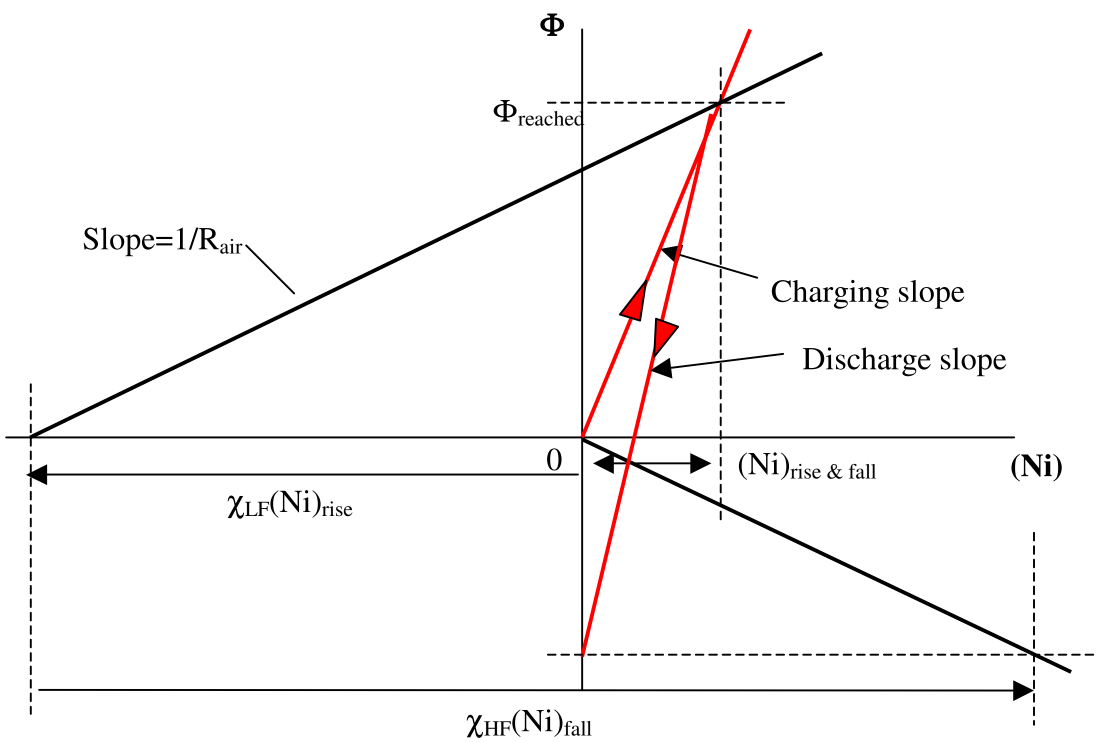


**Figure 6. Slow charge followed by fast discharge**

It is seen that the resonant $\chi_{\mathrm{HF}}\mathrm{Ni}$ during the discharge of current takes the flux through zero into the negative region creating a flux change (voltage*time product) that is greater than that during the charge period, hence the energy recovered is greater then the energy input. Since the $\chi\mathrm{Ni}$ values are all atomic in origin the resonance gives us a window into the otherwise hidden energies supplied by the atomic dipoles.