Using BH Loops

1. Introduction

Plots of B v. H are used extensively in EM theory. Often when plotted over a complete cycle they exhibit hysteresis where the area of the hysteresis loop represents a volume density of energy. For a CCW propagation with time around the loop the area represents energy consumed by the system under study, while a CW propagation represents energy given out. The most common use is for illustrating the characteristics of magnetic material where current is passed through a coil wound onto a closed core. H is established directly from the current and the known core dimensions while B is either measured, requiring an exotic set up, or more simply by integrating the voltage across another coil on the core. However, it is possible to obtain BH loop other than that of the material as are discussed in the next section

2. System BH loops

When there is more than one active coil, a transformer being a good example, BH loops can be derived for each coil where H is established from the current in each coil. In AC transformers using sine waves it is also easy to derive two components of the primary current, the magnetizing component being in phase quadrature to the load current component. Thus, we can derive three different BH loops as shown in Figure 1.

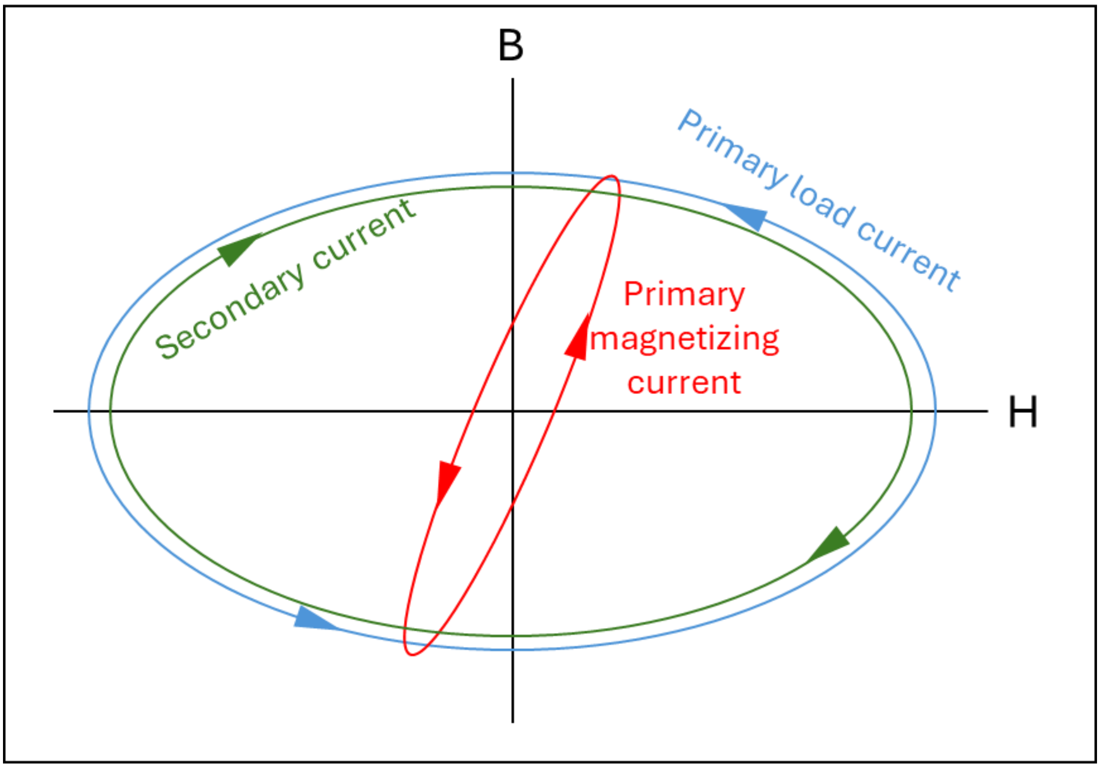

Figure 1

The areas of the two primary loops added together represents energy taken from the source while the area of the secondary loop gives energy fed to the load.

Magnetization M has the same dimension as H, thus it is permissible to plot B v. M. This is done in Figure 2 showing a typical initial rise of B during magnetization.

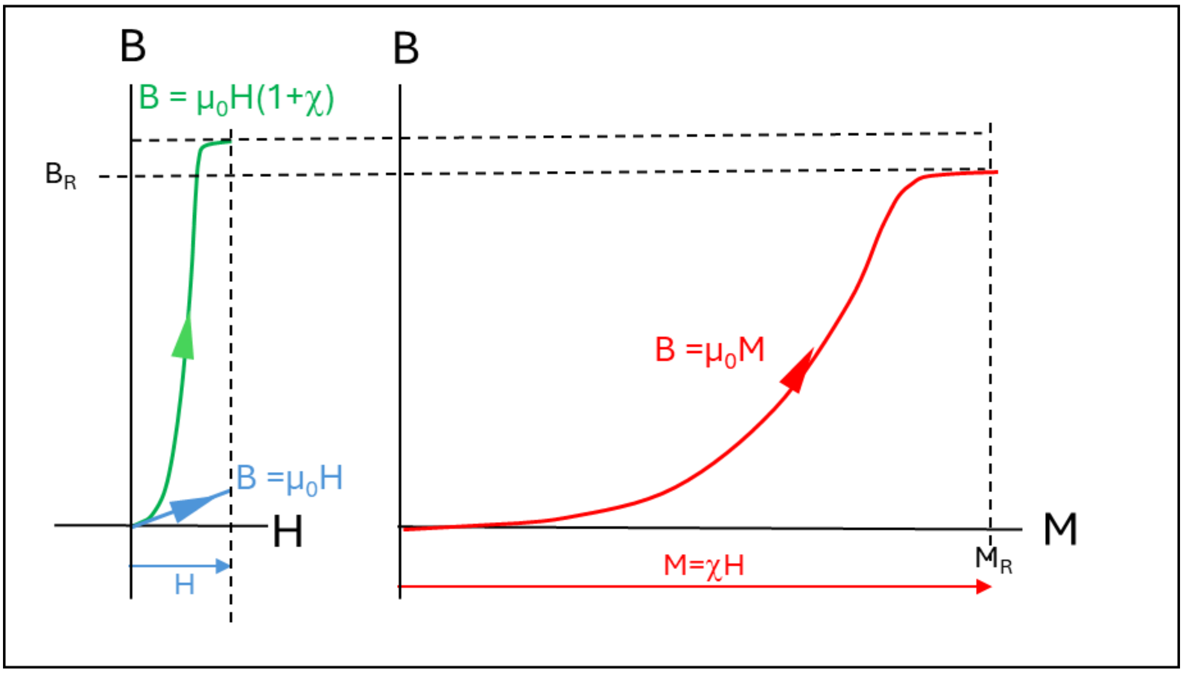

Figure 2

The value of B reached during magnetization comes primarily from M, and the non linear rise is due to the susceptibility χ being a non-linear function of M v. H. For permanent magnet material the remanent M_R value remains when H is returned to zero so the incremental χ value $\frac{dM}{dH}$ is then zero. This is important when consideration is given to M_R decaying naturally and the decaying B within a coil drives current into a load resistor. The H from that current will oppose the change in B and at present we have no evidence for how the variations in the atomic dipoles responsible for the reducing M respond to the opposing H. We can assume that at the initial fall in B, $\frac{dM}{dH}$ is either zero or very close to zero, hence the initial load-current H reached can be a significant proportion of $\frac{B_R}{\mu_0}$ that for typical materials is much greater than the H needed to magnetize. I have shown this in my recent paper "Energy from Remanent Magnetism Decay". It requires measurements to establish how the coil load-current decays with time to see whether regained energy over the full fall of B can exceed the magnetization energy. The Notarial Certificates of the SEMP measurements certainly support that excess energy generation.

3. Magnetization Energy

Figure 3 shows the energy needed to magnetize a core as the yellow area in the B v. H curve.

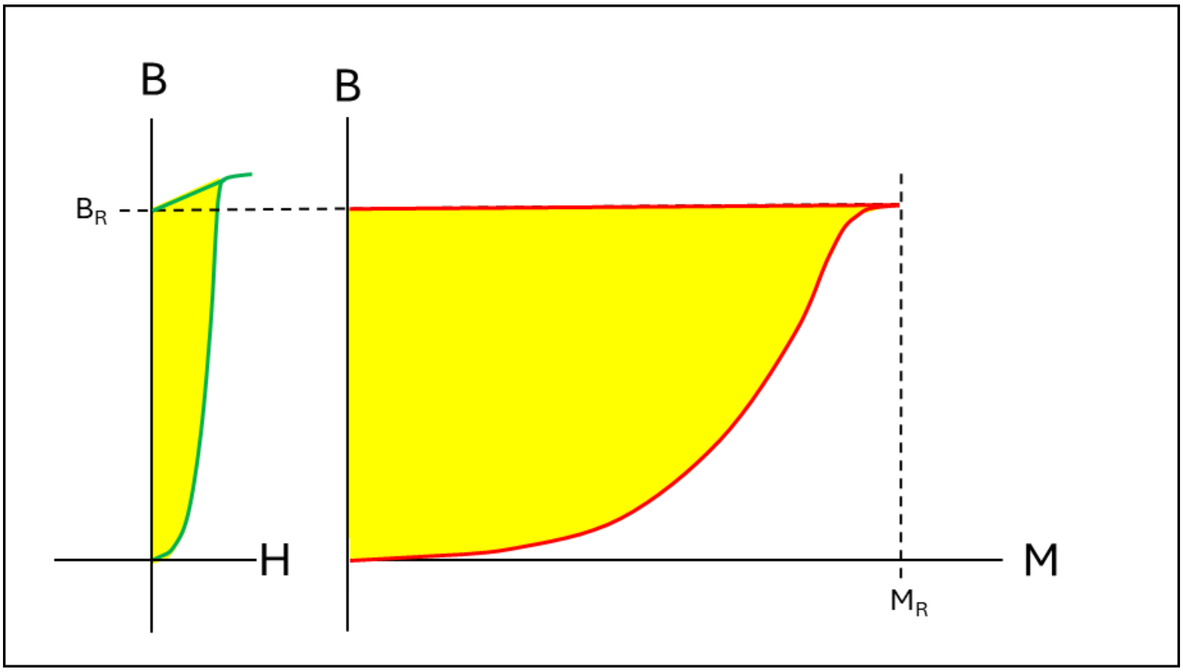

Figure 3

It is pertinent to ask what does the yellow area in the B v. M curve represent? It is quite easy to show that this is the energy stored in *the airspace occupied by the core* assuming that airspace is carrying the remanent B field. Clearly that is a much greater energy than that supplied, but does it have any real significance and if so, where does the excess energy come from? We know that M is really many atomic dipoles that become aligned to produce M_R, and these occupy only a tiny space within the volume. The B field exists within the remaining volume, so that area on the B v M curve could well represent that B field energy. This is further supported by the equivalent surface current concept for a magnetized core where the core can be represented by a current flowing around the surface of *the airspace occupied by the core*. Thus, that area does have real meaning, but it never appears in the math for practicable systems. The energy comes from the atomic current circulations creating the B field, not from the energy required to align them. Those skilled in magnetic science already use *the air space occupied by the core* to determine the effect of an air gap in the otherwise closed core, but few recognize its significance beyond that.

Having established this source of energy within the inter-atomic space that is normally denied to us, we can now consider that energy when remanent magnetism decays naturally. Looking at the equivalent surface current model, where the magnetized core is equivalent to a close wound coil around its surface carrying current, the magnetism can be modelled by that coil as a charged inductor. An inductor connected to a resistor, hence losing its charge as the current decays exponentially. It's energy that initially came from the quantum domain gets fed back to that domain. The relaxation time-constant is then the L/R of that model. When we add our coil connected to a load resistor the combined L/R increases, we obtain some energy in our load with the result that the energy fed back to the quantum load is reduced.

There is the source of our excess energy, the quantum domain is forced to give up some energy but then doesn't get it all back.