Energy from Remanent Magnetism Decay

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1. Introduction

The permanent nature of remanent magnetism has long been utilised in permanent magnets and for storing data. There it is known that "permanent" does not mean for ever, the magnetism does decay over time and for good material this is hundreds of years. Temperature plays its part in the longevity of this remanence where it is known that taking the temperature above the material's Curie temperature Tc destroys the magnetism. That is not a sudden change of characteristic occurring at Tc, the decay rate reduces in a logarithmic manner against temperature, reducing from these hundreds of years at ambient down to fractions of a second at Tc. We could work a material at a temperature below Tc to get any decay time we want, but since we would have to supply energy to magnetize the material and then lose it this has never been done. Until now!! The South Korean SEMP Research Institute claim to have obtained a decay time constant measured in milliseconds in specially heat-treated pure iron, and this has led them to produce equipment that they claim has efficiency that exceeds 100%.

In this paper the math is derived to show that a fast natural decay of remanent magnetism can be used to supply more electrical energy to a load than that required to remagnetise the magnet. Here, to make the math simple, the magnet under consideration is a ring core so all the field remains within the core. This is unusual for those familiar with permanent magnets as remanent magnetism in a ring core has no practical use other than data storage. But nevertheless, it should be obvious if something causes that "permanent" magnetism to decay suddenly the field change can induce voltage hence also current into a resistively loaded coil around the core. What is not obvious to many is that the electrical energy into that load can exceed the energy needed to then remagnetise. If one considers a simple non-electric method to create field reduction, such as the ring core being made in two halves (two horseshoe magnets) that are pulled apart by mechanical force, then there would be no doubt that electrical output from a coil around one or both magnets can exceed the input, energy is supplied mechanically as force times distance work done in pulling apart, followed by energy regained when the attractive force pulls the two halves together. The coil current adds field so that more mechanical energy is needed to pull apart than that regained on the pull back, so the source of that electrical energy is obvious. But internal "permanent" magnetism that suddenly disappears is a new phenomenon that has not received serious consideration in the past, and whatever causes that disappearance could be a source of energy. Here we study the math relating to this mysterious effect to determine the ratio of output energy to remagnetisation energy.

2. Math

For simplicity we assume a ring core that has a perfect square-loop characteristic. Thus, when magnetized the core has a remanent field B_R along with a remanent magnetization M_R. Square-loop means that the MH loop is a rectangle, across the top and bottom M remains constant. The BH loop is different, across the top and bottom the B v. H line has a slope of μ_0. Figure 1 shows both loops. The ring core has a magnetic path length *l* and an area *A*.

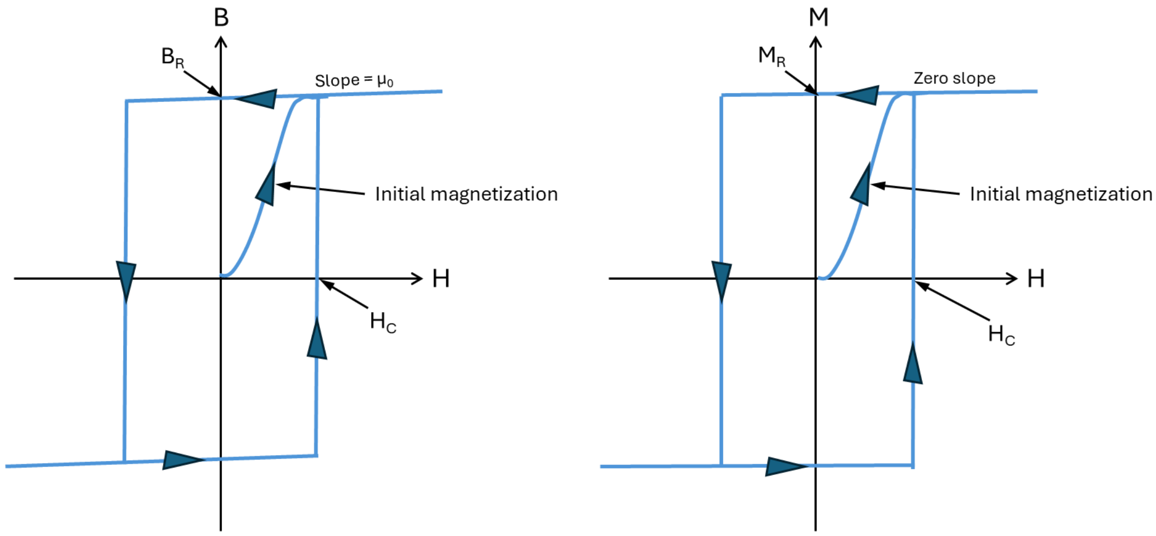

Figure 1. B v. H and M v. H Loops

It is known that M decays exponentially from its initial value M_R, we have

$$M_{[t]} = M_R exp\left(-\frac{t}{\tau}\right) \tag{1}$$

where τ is the relaxation time.

We note that M v. H has zero slope at the remanent point hence the core material's incremental susceptibility is zero, the magnetized core appears as an air core. In the magnetic domain we have *M* creating a mmf *U* given by

$$U = Ml \tag{2}$$

where *l* is the magnetic length of the core. The start value U_0 of this mmf is then

$$U_0 = M_R l \tag{2a}$$

where M_R is the remanent magnetism shown in Figure 1.

This mmf drives flux ϕ into the air-core reluctance R_M given by

$$R_M = \frac{l}{\mu_0 A} \tag{3}$$

where *A* is the core area.

A coil of N turns wound on the core feeding a load resistor R_{LOAD} will appear in the magnetic circuit as a series magnetic inductance L_M, where

$$L_M = \frac{N^2}{R_{LOAD}} \tag{4}$$

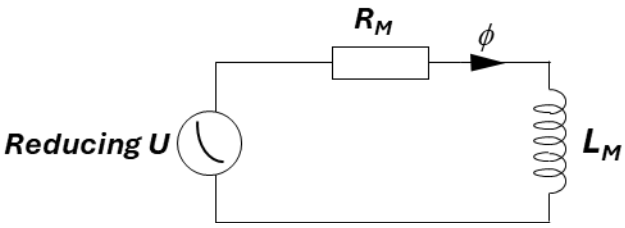

Figure 2

Figure 2 shows the magnetic circuit. Summing the mmfs around the closed circuit gives

$$U_0 exp\left(-\frac{t}{\tau}\right) - \Phi R_M - L_M \frac{d\Phi}{dt} = 0 \tag{5}$$

This can be manipulated into the first order differential equation

$$\frac{d\Phi}{dt} + \frac{\Phi R_M}{L_M} = \frac{U_0}{L_M} exp\left(-\frac{t}{\tau}\right) \tag{6}$$

Using the magnetic time constant

$$\frac{L_M}{R_M} = T \tag{7}$$

the solution is

$$\phi = \frac{U_0}{L_M\left(\frac{1}{T} - \frac{1}{\tau}\right)} exp\left(-\frac{t}{\tau}\right) + C exp\left(-\frac{t}{T}\right) \tag{8}$$

where C is the constant of integration. Solving for C, at $t = 0$ where $\phi_0 = \frac{U_0}{R_M}$ we have

$$C = \frac{U_0}{R_M} - \frac{U_0}{L_M\left(\frac{1}{T} - \frac{1}{\tau}\right)} \tag{9}$$

The solution then is

$$\phi = U_0\left[\frac{1}{R_M} exp\left(-\frac{t}{T}\right) - \frac{1}{L_M\left(\frac{1}{T} - \frac{1}{\tau}\right)} exp\left(-\frac{t}{T}\right) + \frac{1}{L_M\left(\frac{1}{T} - \frac{1}{\tau}\right)} exp\left(-\frac{t}{\tau}\right)\right]$$

(10)

Recasting this to show ϕ_0 we finally have the decaying flux waveform. This includes the effect of the load resistor within the value of *T*, see (4) and (7).

$$\phi = \phi_0 \left[\frac{\tau}{(\tau - T)} exp\left(-\frac{t}{\tau}\right) - \frac{T}{(\tau - T)} exp\left(-\frac{t}{T}\right)\right]$$

(11)

This leads to a mmf U_L across the magnetic inductor L_M from

$$U_L = -L_M \frac{d\phi}{dt} = \phi_0 L_M \left[\frac{T}{T(\tau - T)} exp\left(-\frac{t}{T}\right) - \frac{\tau}{\tau(\tau - T)} exp\left(-\frac{t}{\tau}\right)\right]$$

(12)

That U_L is the ampere-turns in the output coil so gives us the output power and energy, but here it is more convenient to divide it by the core length *l* to get *H*, then plot this against *B* derived by dividing (11) by the core area *A*. This gives the output CW BH loop for comparison with the input loop.

3. Results

This has been done for a 100 turn coil on the TN 36/23/15 MnZn ferrite core, but assuming perfect square loop, with the results shown in Figure 3 for a series of different load resistor values. The H values are from current in the coil.

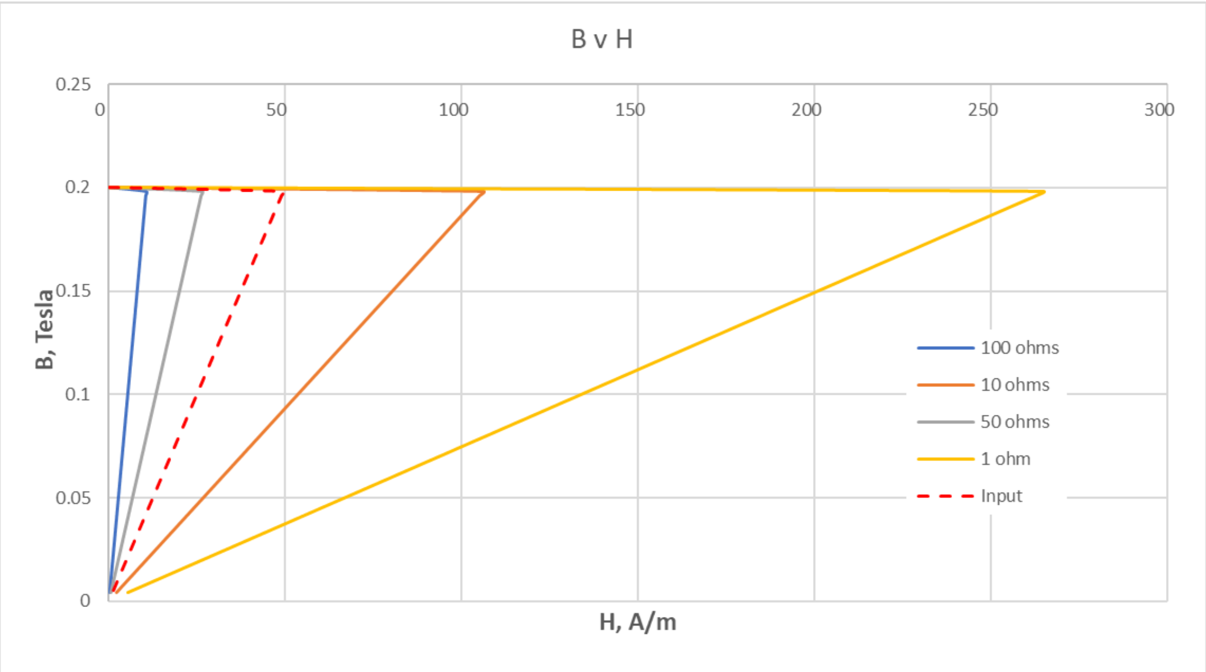

Figure 3 BH Loops

The input loop is traversed CCW while the outputs are traversed CW. The areas of the loops represent energy and as the load resistor is lowered in value the output pulse energy increases to reach values that significantly exceed the input energy.

4. Discussion

The perfect square loop assumption is chosen to see whether a theoretical analysis can lead to an understanding of how self-demagnetization can lead to over-unity results. The TN 36/23/15 MnZn ferrite core does not have a perfect square loop so the results here are not to be expected from experiments with those cores.

Figure 3 shows over-unity occurs when the load current exceeds the initial current needed to saturate the core from zero magnetization. It should be noted that during the magnetizing phase (the input curve in Figure 3) the core has high relative permeability, the slope of that line indicating a value of 3183. That high value comes from the way the atomic dipoles within the material react to the H field from the current in the coil. That reaction is entirely different at saturation because the dipoles are all aligned, and in the perfect square loop they remain aligned after the current is switched off. Initially the self-demagnification is equivalent to current in a coil reducing from a value 3183 times greater that that used to magnetize, and we can't assume the atomic dipoles will react to our load current in the same way they did earlier since it is those very dipole movements that are now creating the current. In Figure 3 the 1-ohm result has a peak load current only 5 times greater than that needed to magnetize, and lower resistor values far exceed this.

In self-demagnification "something" is driving the atomic dipoles to alter their configuration. Our load current is attempting to stop this change, so it is not unreasonable to consider that the "something" is the source of the energy we obtain. In that respect the 3183 times greater current in an imaginary coil acting like the primary of a transformer is not a bad analogy. There is the source of the energy, the magnetic field being the transport mechanism from primary to secondary.

Annex

We have used the symbol M here, but it is now common practise to use the symbol J or J_S that is also used for a surface current density since they both have dimensions of amps/m. Also to further confuse the unwary many texts modify the definition of J so that it has the same dimension as B (Tesla), so their J is really M/μ_0. Then the two curves meet at $J_R = B_R$. The J loop is called the "intrinsic" loop, and the B loop is" normal". Figure 4 is a typical chart.

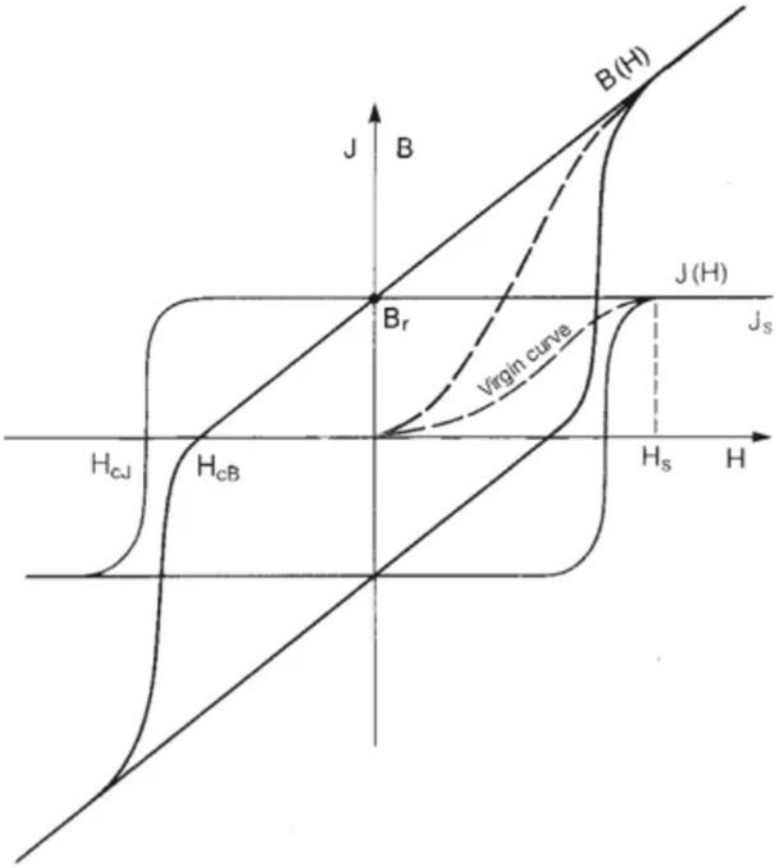

Figure 4