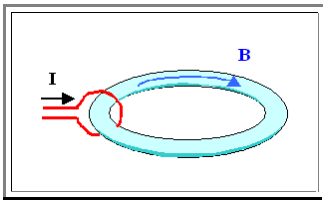


Hystereses Losses

Advanced

Finding the proper formula for the hystereses losses is most easily done by considering the following situation:



- We have a single loop of wire around a doughnut of magnetic material with $R =$ (average) radius of the doughnut or torus of the magnetic material. A current I flows through the wire loop.
- The magnetic field H generated by this arrangement is given by

$$H = \frac{I}{2\pi R}$$

This formula follows straight from the [Maxwell equations](#); it is known as **Ampère's law**.

- The magnetic field H of the wire coil induces a magnetic flux B in the torus.
- If we now imagine that I changes suddenly, e.g. by ΔI in the time interval Δt , to a new constant value, the magnetic flux changes by ΔB , and a voltage U will be induced in the wire coil given by

$$U = \frac{A \cdot \Delta B}{\Delta t}$$

- With $A =$ cross-sectional area of the torus

This is of course nothing but the well-known effect of self-inductance - you cannot turn on a current very quickly that is flowing through a large inductance.

- In our "experiment", however, we just keep the current at the new constant value - even against the effect of the induced voltage that opposes current flow in the wire.
- This requires that we cancel the effect of the induced voltage by raising the outside voltage accordingly. Since we are interested in power losses, we may also argue that we now need to supply power to the system for a while to be able to keep I fixed. Note that in this kind of "experiment" we can make the wire with zero resistance, so no power is fed into the system as long as I does not change

We need to maintain a current I against a voltage U ; this requires the power $P_{\Delta B} = U \cdot I$.

- Using our formulas from above (using $I = 2\pi R \cdot H$) yields

$$P_{\Delta B} = 2\pi R \cdot H \cdot A \cdot \frac{\Delta B}{\Delta t}$$

Power is energy times time; for finding a useful material properties it is advantageous to calculate the energy E deposited in the magnetic material per unit volume

- Dividing by the volume $V = 2\pi R \cdot A$ and forming $E_{\Delta B} = P_{\Delta B} \cdot \Delta t$ gives

$$E_{\Delta B} = H \cdot \Delta B$$

The total energy deposited in an unit volume of the magnetic material during the time it takes to run through *one* cycle of the hystereses curve is obtained by integrating over a complete cycle, i.e.

