Parallel Magnetic Circuits

Fig. 5 shows a magnetic core with an air gap. A coil with ***N*** number of turns is wound around one limb of the core. If ***i*** is the current through the coil, it will produce a flux of in the core. This flux will link the core. A portion ($\boldsymbol{\Phi_2}$) of the flux will link the one limb with the air gap and flux $\boldsymbol{\Phi_1}$ links the other limb of the core. Fig. 5(a) shows the cone with the coil and the flux paths. Fig. 5(b) shows the electrical equivalent of the magnetic circuit. It shows an enample of a series-parallel magnetic circuit.

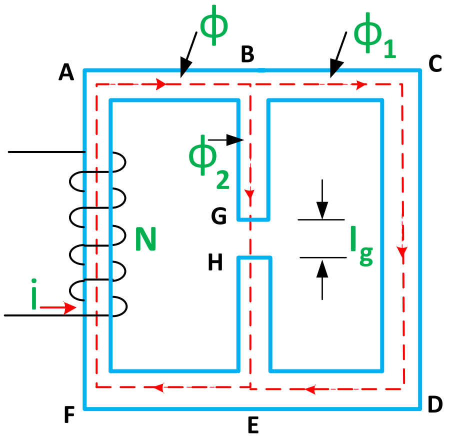

Fig. 5(a)

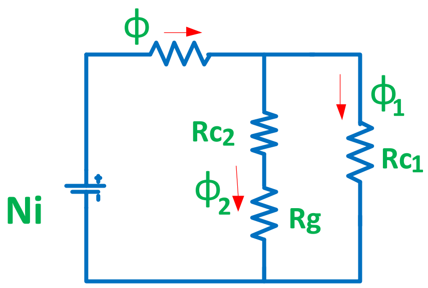

Fig. 5(b)

In Fig. 5(b), the source represents the mmf ($\boldsymbol{F = Ni}$). The flux path (BAFE) with reluctance ***R*** has a flux $\boldsymbol{\Phi}$. The flux $\boldsymbol{\Phi_1}$ links the core BCDE. The reluctance of this flux path is $\boldsymbol{R_{C1}}$. The second path BGHE with flux $\boldsymbol{\Phi_1}$ has two reluctances in series. In this, $\boldsymbol{R_{C2}}$ represents the reluctance of the core part and $\boldsymbol{R_g}$ is the reluctance of the air gap. The values of the reluctances depend on the dimensions, length and cross sectional area, and the permeability of the material.

Inductance

A coil wound on a magnetic core can be represented by an ideal circuit element, called inductance. Inductance is defined as the flux linkage of the coil per unit current. Flux linkage is given as

$$\boldsymbol{\lambda = N\phi}$$

$$\boldsymbol{L = \frac{\lambda}{i} = \frac{N\Phi}{i} = \frac{NBA}{i}}$$

where **λ** is the flux linkage, ***B*** is the flan density and ***A*** is the cross-sectional area. If ***H*** is the magnetic field intensity and ***lc*** is the length of the core, then

$$Hl_c = Ni$$
$$\Rightarrow i = \frac{Hlc}{N}$$

$$L = \frac{NBA}{i} = \frac{N\mu HA}{i} = \frac{N\mu HA}{Hlc/N}$$

$$L = \frac{N^2}{l_c/\mu A} = \frac{N^2}{R}$$

This represents the inductance interms of number of turns of the coil and the reluctance of the core .

Hysteresis (B-H Characteristic)

For various applications, a time-varying or ac current is applied to coil. An ac current changes its amplitude with time. Hence, the magnetic field intensity changes as it is proportional to the current. The flux density is equal to the product of permeability and magnetic field intensity. It is expected that the flux density or the flux will increase with the increase of current and it should decrease with the decrease of current. Fig. 6 shows a typical B-H characteristic.

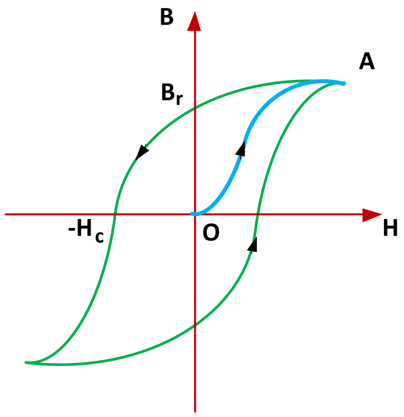

Fig. 6

The B-H characteristics of a magnetic material is non-linear. The flux density increases fnem zero value (0A path) to a maximum value when the material is magnetically saturated. If the field intensity is decreased then the flux density is decreased, but it follows a different path (AC). The flux density has a non-zero value even when the field intensity is zero. This non-zero value of flux density (***Br***) is called the residual flux density, Engineers have used this property of residual magnetism for the design of various electro-mechanical energy convertion devices. The non-zero value ***(Hc)*** of magnetic field intensity for zero flux density is called coercivity on coercive force. This magnetization and demagnetization of the magnetic material can cause loss of energy. This loss is known as Hysteresis loss. The power loss is given as

$$P_H = k_h B_{\max}^n f$$

where ***Kh*** is the hystenens constant, ***Bmax*** is the maximum value of the flux density and ***f*** is the frequency of the ac current in the coil. ***n*** is a constant which defends on the magnetic material and its value varies between 1.5 to 2.5 for a typical magnetic material. There is another form of power loss in a magnetic material. This loss is termed as eddy current loss. It is given as

$$P_e = K_e B_{\max}^2 f^2$$

where ***Ke*** is the eddy current loss constant. The eddy current loss is proportional to the square of the flux density and square of the frequency. Voltages are induced in the magnetic material when it experiences a time varying flux. A current will flow in the magnetic material if a closed bath is present. Based on the resistance of the path, there will be power loss which is known as eddy current loss. Eddy current loss has been used for design of induction cookers.