KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

ELECTRICAL ENGINEERING DEPARTMENT

EE 306 – Term 162

HW # 2: Magnatic Circuits

Solution

Problem # 1:

A coil of 500 turns and resistance 20 Ω is wound uniformly on an iron ring of mean circumference of 50 cm and cross section 4 cm_2. It is connected to a 24-volt DC supply. Under these conditions, the relative permeability of iron is 800. Calculate the values of:

(a) the magnetomotive force.
(b) the magnetic field intensity.
(c) the total flux in the iron.
(d) the reluctance of the ring.

$$I = \frac{24}{20} = 1.2 \text{ A}$$

a) $F = NI = 1.2 * 500 = 600 \text{ AT}$

b) $H = \frac{F}{l} = \frac{600}{0.5} = 1200 \text{ AT/m}$

c) $B = \mu H = \mu_o \mu_r H = 4\pi * 10^{-7} * 800 * 1200 = 1.206 \text{ T}$

$\Phi = BA = 1.206 * 4 * 10^{-4} = 0.483 \text{ mWb}$

d) $\mathcal{R} = \frac{l}{\mu A} = \frac{0.5}{4\pi * 10^{-7} * 800 * 4 * 10^{-4}} = 1.243 * 10^{6} \text{ AT/Wb}$

Problem # 2:

A square magnetic core has a mean path length of 55 cm and a cross-sectional area of 150 cm2. A 200-turn coil of wire is wrapped around one leg of the core. The magnetization curve of the core material is shown in Fig. 1.

(a) How much current is required to produce 12 mWb of flux in the core?

(b) What is the relative permeability of the core at that level of current?

(c) What is its reluctance?

(d) Repeat part (a) if an air-gap of length 1 mm is cut across the core.

Assume a 5% increase in the effective air-gap area to account for fringing.

$$B = \frac{\Phi}{A} = \frac{0.012}{0.015} = 0.8\ T$$

From the magnetization curve, the corresponding H

$H \cong 115$ AT/m

Hence, $F = Hl = 115 * 0.55 = 63.25$ AT

So,

a) $I = \frac{F}{N} = \frac{63.25}{200} = 0.316$ A

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b) $\mu = \frac{B}{H} = \frac{0.8}{115} = 0.00696$ H/m

$\mu_r = \frac{\mu}{\mu_0} = \frac{0.00696}{4\pi * 10^{-7}} = 5540$

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c) $\mathcal{R} = \frac{F}{\Phi} = \frac{63.25}{0.012} = 5270$ AT/Wb

or, $\mathcal{R} = \frac{l}{\mu A} = \frac{0.55}{5540 * 4\pi * 10^{-7} * 150 * 10^{-4}} = 5270$ AT/Wb

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d) With the same flux $\Phi = 12$ mWb, $B_c = 0.8$ T

$H_c = 115$ AT/m, $l_c = 0.55$ m (Neglect l_g; $l_g \ll l_c$)

$B_g = \frac{\Phi}{A_g} = \frac{0.012}{1.05 * 150 * 10^{-4}} = 0.762$ T

$H_g = \frac{B_g}{\mu_0} = \frac{0.762}{4\pi * 10^{-7}} = 0.061 * 10^{7}$ AT/m, $F_g = H_g l_g$

$F_{total} = F_c + F_g = 63.25 + 0.061 * 10^{7} * 1 * 10^{-3} = 673.25$

$I = \frac{F_{tot}}{N} = \frac{673.25}{200} = 3.366$ A

Problem # 3:

The total core loss for a specimen of magnetic sheet steel is found to be 1800 W at 60 Hz. If the flux density is kept constant and the frequency of the supply increases 50%, the total core loss is found to be 3000 W. Compute the separate hysteresis and eddy-current losses at both frequencies.

For Constant B

$P_h \propto f$ i.e. $P_h = Af$ where A is Const.

$P_e \propto f^2$ i.e. $P_e = Bf^2$ " B " "

at 60 Hz

$$1800 = A * 60 + B * (60)^2 \longrightarrow (1)$$

at 90 Hz

$$3000 = A * 90 + B * (90)^2 \longrightarrow (2)$$

(1) by 3 and (2) by 2 and subtract

$$3 * 1800 - 2 * 3000 = 3B * (60)^2 - 2B * (90)^2$$

$$-600 = -5400 B$$

So, $B = 0.111$ sub. in (1)

$A = 23.333$

Hence; At 60 Hz

$P_h = 23.333 * 60 = 1400$ W

$P_e = 0.111 * (60)^2 = 400$ W

At 90 Hz

$P_h = 23.333 * 90 = 2100$ W

$P_e = 0.111 * (90)^2 = 900$ W

1.9 (a) Mean length of core, $l_c = 2\pi \frac{(10+6)}{2} \times 10^{-2}\ m = 0.503\ m$

For cast steel $H_c = 1000\ At/m$ at $B = 1.2T$.

$$i = \frac{H_c l_c}{N} = \frac{1000 \times 0.503}{200} = 2.51\ A.$$

(b)

$$A_c = \pi (2 \times 10^{-2})^2 = 1.26 \times 10^{-3}\ m^2$$

$$\Phi_c = A_c B_c = 1.26 \times 10^{-3} \times 1.2 = 1.51 \times 10^{-3}\ Wb$$

(c)

$$Ni = H_c l_c + H_g l_g = H_c l_c + \frac{B_g}{\mu_0} l_g$$

$$i = \frac{1000 \times 0.503}{200} + \frac{1.2 \times 2 \times 10^{-3}}{4\pi 10^{-7} \times 200} = 12.06\ A$$

1.15 (a) $B_v = 0.6\ T$, $B_h = \frac{1.5}{1.0} \times 0.6 = 0.9\ T.$

$l_v = 7 \times 2 = 14\ cm$, $l_h = 7.5 \times 2 = 15\ cm.$

$H_v = 400 \times \frac{0.6}{0.8} = 300\ A.t/m.$

$H_h = 400 + \frac{1000 - 400}{2} = 700\ A.t/m.$

$F = H_h l_h + H_v l_v = 700 \times 0.15 + 300 \times 0.14 = 147\ A.t$

$F = I_1 N_1 + I_2 N_2 = 2 \times 200 + I_2 \times 100 = 147\ A.t$

$I_2 = -2.53\ A.$

1.18 Area of B-H loop $= 20 \times 2.4 = 48$

Volume of core $= 15 \times 10^{-2} \times 10 \times 10^{-4} = 15 \times 10^{-5}\ m^3$

$P_h = 15 \times 10^{-5} \times 48 \times 400 = 2.88\ W$