Announcements

• SAIS open now – please fill it out
  – Remaining students:
    • 15 in 481
    • 20 in 599
• Final Exam:
  – Posted online after final class
  – Due before end of scheduled exam time
    • Monday, Dec 9th, 10:00 am

13.3 Magnetics Losses

- Magnetic Device Losses
  - Copper Loss
  - Core Loss
    - Eddy Current
    - Residual
    - Hysteresis

- Skin Effect
- Proximity Effect
- Fringing Flux

High Frequency Losses
The $K_g$ Method

1. $L_k = \frac{\text{Inc} \times A_c}{f_g}$
2. $I_{\text{max}} = \frac{\text{Bmax} \times I_g}{n \times m}$
3. $A_{\text{wall}} = K_u \times W_A$
4. $R = \frac{\rho \times \text{MLT}}{A_w}$

$K_g$ Method

1. Solve circuit equation for $L$, $I_{\text{max}}$, $R$

Notes:
1. Only DC copper loss is included. Should check core loss after to make sure it is acceptable.
2. May need to iterate due to rounding to integer $n$, $A_w$.
Discussion

\[ K'_{\text{eff}} = \frac{A^2 W_A}{(MLT)} \geq \frac{\rho L^2 I_{\text{max}}^2}{B_{\text{max}}^2 R K'_{\text{eff}}} \]

\( K'_{\text{eff}} \) is a figure-of-merit that describes the effective electrical size of magnetic cores, in applications where the following quantities are specified:

- Copper loss
- Maximum flux density

How specifications affect the core size:

- A smaller core can be used by increasing
  - \( B_{\text{max}} \Rightarrow \) use core material having higher \( B_{\text{sat}} \)
  - \( R \Rightarrow \) allow more copper loss

How the core geometry affects electrical capabilities:

- A larger \( K'_{\text{eff}} \) can be obtained by increase of
  - \( A_A \Rightarrow \) more iron core material, or
  - \( W_A \Rightarrow \) larger window and more copper

Alternate Applications

- Can be applied to multiple-winding magnetics as long as design goals apply
  - Core loss negligible
  - Saturation is limiting peak flux density
- 14.3 shows how the method changes
Chapter 15: Transformer Design

15.1 Transformer design: Basic constraints
15.2 A step-by-step transformer design procedure
15.3 Examples
15.4 AC inductor design
15.5 Summary
**Transformer Design Constraints**

Design Goals:
1. Correct Turns Ratios
2. Minimize Power Loss: \( P_{\text{Loss}} = P_{\text{Fe}} + P_{\text{Cu}} \)

Design Parameters:
1. \( n \)
2. Core

**Power Loss Tradeoffs**

\[ P_{\text{Fe}} = A_{\text{Fe}} \ln K_{\text{Fe}} (AB)^B \sqrt{L} \]
\[ P_{\text{Cu}} = \sum_{\text{all windings}} I_{\text{m}ij}^2 \rho A_{\text{mij}} \frac{MLT}{A_{\text{mij}}} \]
\[ \Delta B = \frac{1}{N_{\text{Fe}}} \int N_{\text{Fe}} \, dI \]
\[ P_{\text{Loss}} = P_{\text{Fe}} + P_{\text{Cu}} \]

\[ \min(P_{\text{loss}}) = \frac{\partial P_{\text{Fe}}}{\partial n} = 0 \]
Minimizing Total Loss

There is a value of $\Delta B$ that minimizes the total power loss:

$$P_{\text{tot}} = P_{c} + P_{e}$$

$$P_{c} = K_c (\Delta B)^6 A_c \ell_m$$

$$P_{e} = \left( \frac{\nu \lambda_e^2 I_{e0}^2}{4 K_u} \right) \left( \frac{(MLT)}{W_A A_e^2} \right) \left( \frac{1}{\Delta B} \right)^2$$

Calculation of Total Loss

Substitute optimum $\Delta B$ into expressions for $P_{c}$ and $P_{e}$. The total loss is:

$$P_{\text{tot}} = A_c \ell_m K_c \left( \frac{\beta}{2} \right)^2 \left( \frac{\nu \lambda_e^2 I_{e0}^2}{4 K_u} \right) \left( \frac{(MLT)}{W_A A_e^2} \right) \left( \frac{1}{\Delta B} \right)^2$$

Rearrange as follows:

$$K_{S_{\text{eff}}} = \frac{W_A(A_c)^2}{(MLT)} \left( \frac{\beta}{2} \right)^2 \left( \frac{\nu \lambda_e^2 I_{e0}^2}{4 K_u} \right) \left( \frac{1}{\Delta B} \right)^2$$

Left side: terms depend on core geometry

Right side: terms depend on specifications of the application
The $K_{gfe}$ Method

Define

$$K_{gfe} = \frac{W_A[A_1]^{(3B-1)\beta}}{(MLT)L_m} \left( \frac{B}{2} \right)^{\frac{3}{2}} \left( \frac{B}{2} \right)^{\frac{1}{2}}$$

Design procedure: select a core that satisfies

$$K_{gfe} \geq \frac{\rho \lambda^2 I_r^2 K_{fe}^{(2)\beta}}{4K_{c}(P_{tot})([6+2)\beta]}$$

Appendix D lists the values of $K_{gfe}$ for common ferrite cores

$K_{gfe}$ is similar to the $K_s$ geometrical constant used in Chapter 14:

- $K_s$ is used when $B_{max}$ is specified
- $K_{gfe}$ is used when $\Delta B$ is to be chosen to minimize total loss

Verify $B_{max} < B_{sat}$