PART IIA 2005

3B4 Electric drive systems

NUMERICAL ANSWERS

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1.

$\mu0 := 4\cdot\pi\cdot 10^{-7}\cdot\frac{henry}{m}$ $\qquad i := 1..4$

Alnico := 1 $\qquad$ Ceramic := 2 $\qquad$ SmCo := 3 $\qquad$ NdFeB := 4

$Br_i :=$	$Hc_i :=$
$1.32\cdot tesla$	$56000\cdot\frac{amp}{m}$
$0.39\cdot tesla$	$176000\cdot\frac{amp}{m}$
$1.06\cdot tesla$	$815000\cdot\frac{amp}{m}$
$1.21\cdot tesla$	$840000\cdot\frac{amp}{m}$

$$\mu r_i := \frac{Br_i}{\mu0\cdot Hc_i}$$

$$BHmax_i := \frac{Br_i\cdot Hc_i}{4}$$

a)

$$\mu r = \begin{bmatrix} 0 \\ 18.758 \\ 1.763 \\ 1.035 \\ 1.146 \end{bmatrix} \begin{matrix} \\ \text{Alnico} \\ \text{Ceramic} \\ \text{SmCo} \\ \text{NdFeB} \end{matrix}$$

b)

$$BHmax = \begin{bmatrix} 0 \\ 1.848\cdot 10^4 \\ 1.716\cdot 10^4 \\ 2.16\cdot 10^5 \\ 2.541\cdot 10^5 \end{bmatrix}\cdot m^{-3}\cdot joule \quad \begin{matrix} \\ \text{Alnico} \\ \text{Ceramic} \\ \text{SmCo} \\ \text{NdFeB} \end{matrix}$$

c)

d) i) 4/9 of original energy product ii) 4/9 of original energy product

2.

$\delta := 30\cdot deg$ $\qquad Xqs := 1\cdot ohm$ $\qquad Xds := 2\cdot ohm$ $\qquad R := 1\cdot ohm$

$$voltage := \frac{6.6\cdot 10^3}{3^{0.5}}\cdot volt$$

$$Power := 3\cdot voltage^2\cdot\left[\left[\frac{\sin(\delta)\cdot\cos(\delta) - \frac{R}{Xds}\cdot(\cos(\delta))^2}{Xqs + \frac{R^2}{Xds}}\right] - \left[\frac{\sin(\delta)\cdot\cos(\delta) - \frac{R}{Xqs}\cdot(\sin(\delta))^2}{Xds + \frac{R^2}{Xqs}}\right]\right]$$

$Power = -8.233\cdot 10^6 \cdot watt$

3.

4. $i := 1..3$ $\quad start := 1$ $\quad end := 2$ $\quad ambient := 193 \cdot K$

$period_i :=$ $\quad temperature\_above\_ambient_{start,i} :=$ $\quad temperature\_above\_ambient_{end,i} :=$

$$period = \begin{pmatrix} 10 \cdot 60 \cdot sec \\ 2 \cdot 60 \cdot sec \\ 3 \cdot 60 \cdot sec \end{pmatrix} \qquad temperature\_above\_ambient_{start} = \begin{pmatrix} 0 \cdot K \\ 50 \cdot K \\ 20 \cdot K \end{pmatrix} \qquad temperature\_above\_ambient_{end} = \begin{pmatrix} 50 \cdot K \\ 20 \cdot K \\ 60 \cdot K \end{pmatrix}$$

$$tau := -\left[\frac{period_2}{\ln\left(\frac{temperature\_above\_ambient_{end,2}}{temperature\_above\_ambient_{start,2}}\right)}\right]$$

$tau = 130.963 \cdot sec$ $\qquad k := 1.1 \cdot \frac{watt}{K}$

$C := tau \cdot k$

$C = 144.059 \cdot joule \cdot K^{-1}$

c)

i) at half-power (steady state power dissipation)

$$T\_infinity := \frac{temperature\_above\_ambient_{end,1}}{1 - e^{\left(\frac{-period_1}{tau}\right)}} + ambient$$

$T\_infinity = 243.517 \cdot K$

$Pdiss := k \cdot (T\_infinity - ambient)$

$Pdiss = 55.569 \cdot watt$

ii) at full-power (steady state power dissipation)

$$T\_infinity := \frac{temperature\_above\_ambient_{end,3}}{1 - e^{\left(\frac{-period_3}{tau}\right)}} + ambient$$

$T\_infinity = 273.319 \cdot K$

$Pdiss := k \cdot (T\_infinity - ambient)$

$Pdiss = 88.351 \cdot watt$

$Pmech := 1000 \cdot watt$

$$Pmech = Pdiss \cdot \frac{(1-s)^2}{s \cdot (2-s)}$$

$$s := \begin{bmatrix} \frac{1}{(2 \cdot (Pmech + Pdiss))} \cdot \left(2 \cdot Pmech + 2 \cdot Pdiss + 2 \cdot \sqrt{Pmech} \cdot \sqrt{Pmech + Pdiss}\right) \\ \frac{1}{(2 \cdot (Pmech + Pdiss))} \cdot \left(2 \cdot Pmech + 2 \cdot Pdiss - 2 \cdot \sqrt{Pmech} \cdot \sqrt{Pmech + Pdiss}\right) \end{bmatrix}$$

$$s = \begin{pmatrix} 1.959 \\ 0.041 \end{pmatrix}$$