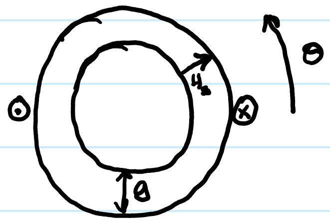
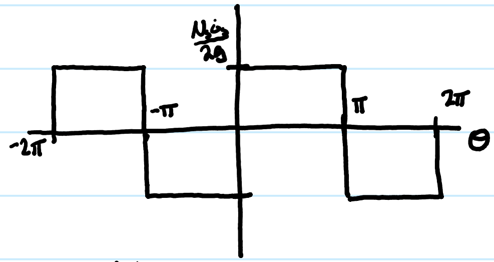
2018-11-30-1

Pulsating magnetic fields





$H_s \approx \frac{N_s i_s}{2g} \sin(\theta)$

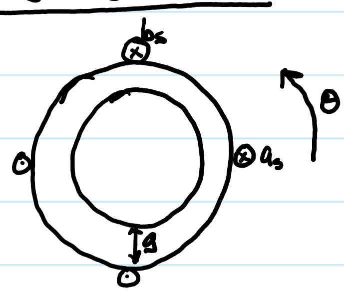
Assume: $i_s = I_s \cos(\omega_s t)$

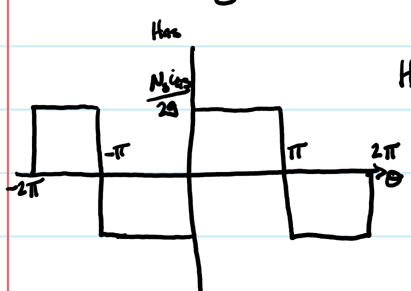
$H_s \approx \frac{N_s I_s}{2g} \cos(\omega_s t) \sin(\theta)$

at $t=0$: H_s max at $\theta = \frac{\pi}{2}$

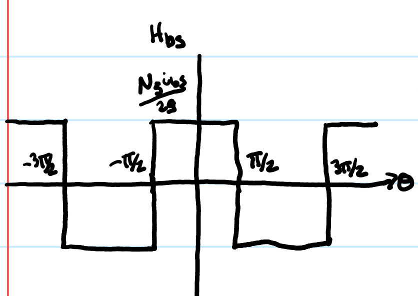
at $t=\varepsilon$: H_s max at $\theta = \frac{\pi}{2}$

Rotating magnetic field:





$H_{as} \approx \frac{N_s i_{as}}{2g} \sin(\theta)$



$H_{bs} \approx \frac{N_s i_{bs}}{2g} \cos(\theta)$

$H_s = H_{as} + H_{bs}$

Assume: $i_{as} = I_s \sin(\omega_s t)$, $i_{bs} = I_s \cos(\omega_s t)$

$H_s = \frac{N_s I_s}{2g}\left[\sin(\theta)\sin(\omega_s t) + \cos(\theta)\cos(\omega_s t)\right]$

$H_s = \frac{N_s I_s}{2g} \cos(\omega_s t - \theta)$

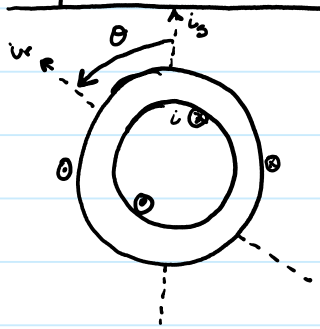
at $t=0$: max at $\theta = 0$

at $t=\varepsilon$: max at $\theta = \omega_s \varepsilon$

$\boxed{H_s \text{ rotates counterclockwise}}$

2018-11-30-2

Synchronous machines:



$$\lambda_s = L_s i_s + M\cos(\theta)\, i_r$$
$$\lambda_r = M\cos(\theta)\, i_s + L_r i_r$$

$$W_m' = \frac{1}{2}\left(L_s i_s^2 + L_r i_r^2\right) + M\cos(\theta)\, i_s i_r$$
$$T^e = \frac{\partial W_m'}{\partial \theta} = -M\sin(\theta)\, i_s i_r$$

Assume: $i_s = I_s\cos(\omega_s t)$

$i_r = I_r\cos(\omega_r t)$

$$T^e = -M I_s I_r \cos(\omega_s t)\cos(\omega_r t)\sin(\theta)$$
$$T^e = -M I_s I_r \sin(\theta)\left[\frac{\cos(t(\omega_s+\omega_r)) + \cos(t(\omega_s-\omega_r))}{2}\right]$$

<u>Power:</u> $P = T^e \frac{d\theta}{dt} \Rightarrow P = T^e \omega_m \Rightarrow P = -\omega_m M I_s I_r \sin(\theta)\left[\frac{\cos(t(\omega_s+\omega_r)) + \cos(t(\omega_s-\omega_r))}{2}\right]$

<u>Assume:</u> $\sin(\omega t+\gamma) \Rightarrow P = -\omega_m M I_s I_r\left[\frac{1}{2}\left(\sin(\omega_m t+\gamma)\cos(t(\omega_s+\omega_r)) + \sin(\omega_m t+\gamma)\cos(t(\omega_s-\omega_r))\right)\right]$

$$\boxed{\begin{gathered} P = -\frac{1}{4}\omega_m M I_s I_r\left[\sin(\omega_1 t+\gamma) + \sin(\omega_2 t+\gamma) + \sin(\omega_3 t+\gamma) + \sin(\omega_4 t+\gamma)\right] \\ \omega_1 = \omega_m + \omega_s - \omega_r \qquad \omega_3 = \omega_m + \omega_s + \omega_r \\ \omega_2 = \omega_m - \omega_s + \omega_r \qquad \omega_4 = \omega_m - \omega_s - \omega_r \end{gathered}}$$

For a non-zero average power, need 1 of the ω's $= 0$

$P_{avg} = -\frac{1}{4}\omega_m I_s I_r M \sin(\gamma)$

* But, also have pulsating torque due to the other ω's!