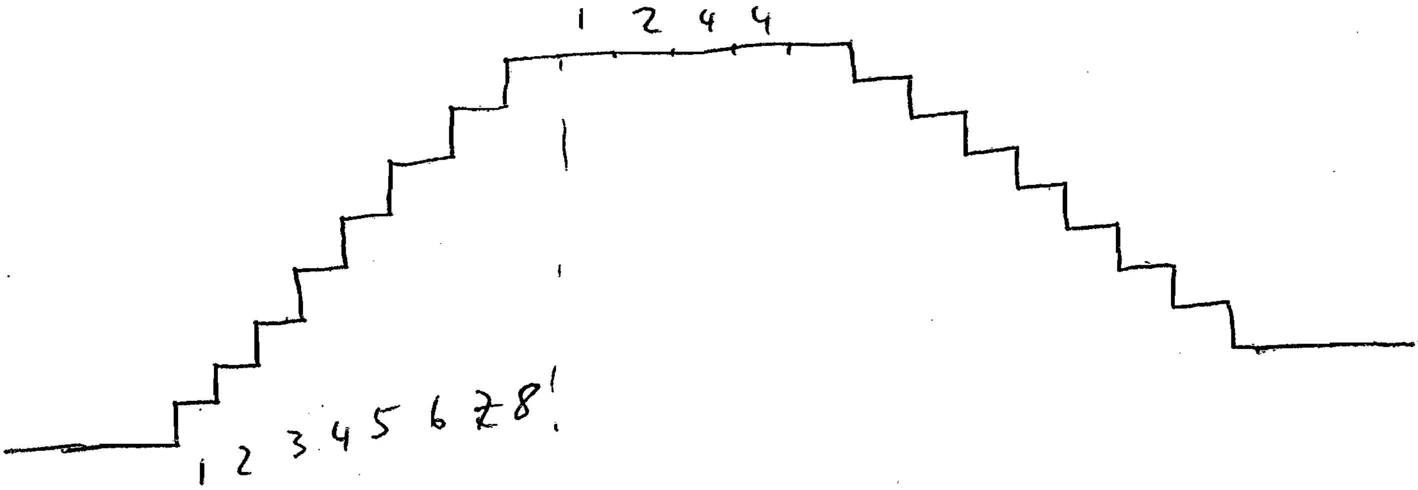
1(a) Distributed winding refers to the way a coil side is spread between a number of slots. In three phase motors (higher powers) everything should be sinusoidal and distribution gives a more sinusoidal mmf.

(b) The main winding is in bands of 8 slots. Since the motor is single phase, the second winding is simply for starting, so does not need to be well distributed or thick wire. 8 slots means 8 steps.



$$F(\theta) = \frac{N_{eff} I}{2} \cos(\theta) \qquad I(t) = \hat{I} \cos \omega t.$$

$$F(\theta, t) = \frac{N_{eff}}{2} \hat{I} \cos(\omega t) \cos(\theta)$$

$$= \frac{N_{eff}}{4} \hat{I} \left[\cos(\omega t + \theta) + \cos(\omega t - \theta) \right]$$

PART IIA 2007
3B4 Electric drive systems
Dr P Palmer

1/(b) cont.

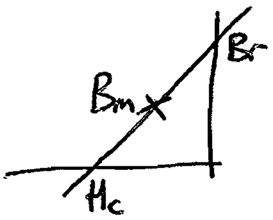
$$S = \frac{\pi^2}{\sqrt{2}} \left(\frac{d}{2}\right)^2 . l . \frac{\omega}{p} \times \bar{B} \times \bar{J}$$

$$= \frac{\pi^2}{\sqrt{2}} , (0.025)^2 \times 0.03 \times \frac{2\pi.50}{1} \times 0.5 \times 3 \times 10^4 .$$

$= 617$ VA $\quad \eta = 0.8$, $\cos\phi = 0.8$

$\Rightarrow 395$ W.

(c) $SmCo_5$ has a straight line. B-H. curve in the demagnetisation region. Aim for the mid point.



$B_m = B_r/2 \quad \mu_m = \frac{B_r}{H_c}$ $\qquad B_m = \mu_m H_m + B_r .$

Assume infinitely permeable iron.

$H_m l_m + H_g l_g = 0 \qquad B_g A_g = B_m A_m .$

$$B_m = \mu_0 H_g \frac{A_g}{A_m} . = -\mu_0 H_m \frac{l_m}{l_g} \frac{A_g}{A_m}$$

$\qquad H_m = \frac{B_m - B_r}{\mu_m} .$

$B_m = B_r/2$

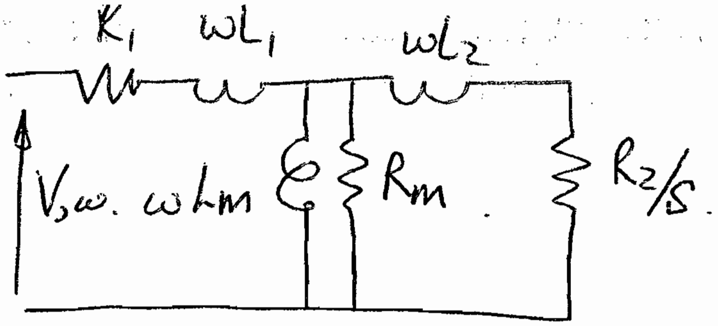
$$\frac{B_r}{2} = -\frac{\mu_0}{\mu_m} . \left(\frac{B_r}{2} - B_r\right) . \frac{l_m}{l_g} \frac{A_g}{A_m} .$$

$$1 = \frac{\mu_0}{\mu_m} \frac{l_m}{l_g} . \frac{A_g}{A_m}$$ and minimise the airgap.

24 slots, 3 phase. 8 slots per phase.

More efficient & quiet with adjustable speed but needs an inverter.

4 (a)



When commissioned as part of a variable speed drive, V/f = const, so $\frac{V}{\omega L_m}$ = const and smallish. Since ω is variable, the value of R_2/s should be large compared to R_1 and ωL_1 under all conditions (i.e. we work at small $s.\omega$).

Having a very low V at very low ω's means that IR_1 becomes significant at low ω's. This is dealt with separately by "voltage boosting", or a simple calculation.

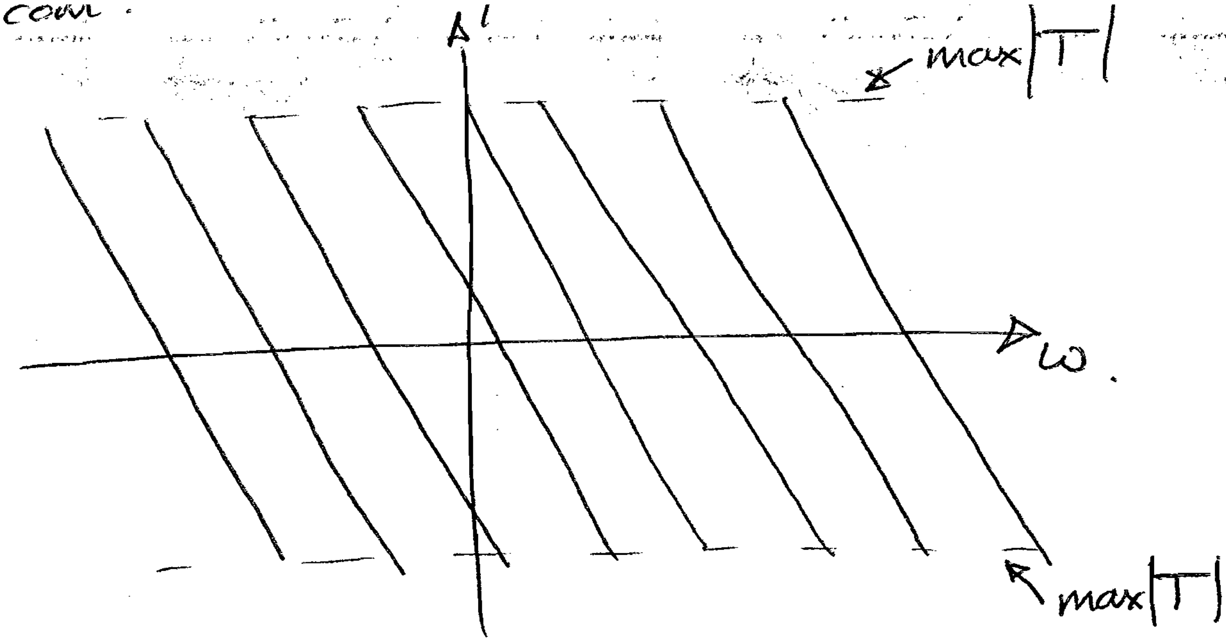
Ignoring R_1 & ωL_1 and ωL_2

$$\omega T = \frac{3V^2}{R_2/s} \quad T = \frac{3V^2}{\omega^2} \cdot \frac{s\omega}{R_2}$$

So max T means max $s\omega$. $\Rightarrow$ $s_{rated}\,\omega_{rated}$

$$T_{max} = \frac{3\,V_{rated}^2}{\omega_{rated}^2} \cdot \frac{s_{rated}\,\omega_{rated}}{R_2}.$$

2(a) cont.



Above base speed, the V becomes fixed.

$I = V/(R_2/s)$ $I_{rated} = V_{rated}/(R_2/s)$ so (R_2/s) is fixed also.

$T = \frac{3V^2}{\omega^2} \cdot \frac{s\omega}{R_2}$ (i.e., $T_{max} \propto \frac{1}{\omega}$) $s\omega = (\omega_s - \omega_r)$

$\frac{dT}{d\omega_r} = -\frac{3V^2}{\omega^2} \cdot \frac{1}{R_2}$ so as ω increases the slope goes down.

2 (b) $T\omega = 3V_1^2 \frac{R_2/s}{(R_2/s)^2 + \omega^2 L_2^2}$

max T when $R_2 = s\omega L_2 \Rightarrow s\omega = \frac{R_2}{L_2}$

$\therefore T\omega = 3V_1^2 \cdot \frac{R_2/s}{2(R_2/s)^2} = 3V_1^2 \frac{s}{2R_2}.$

$4kW = 3 \cdot \left(\frac{415}{\sqrt{3}}\right)^2 \cdot \frac{s}{2 \times 2.14} \Rightarrow s = 0.1$

$\omega = \frac{R_2}{sL_2} = \frac{2.14}{0.1 \times 6/100\pi} = \frac{2.14}{6} \times 1000\pi$ rads/sec.

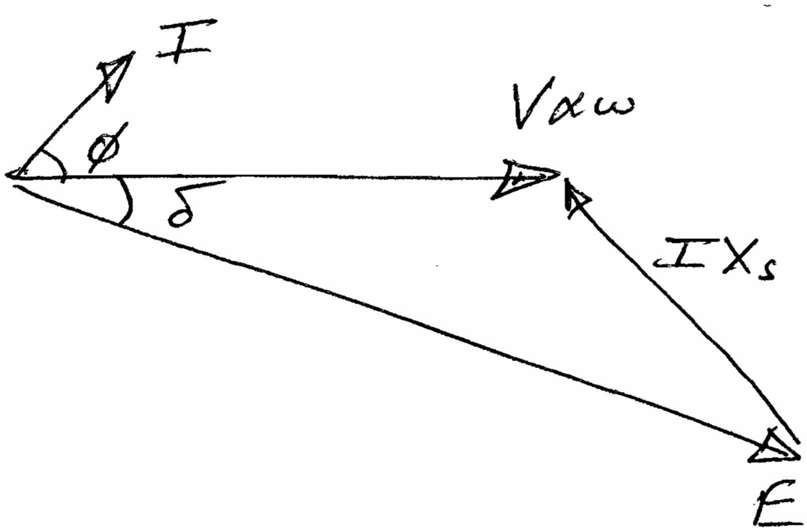
(178.3 Hz)

noting 0.1 slip $\omega_r = 0.9 \times \frac{2.14}{6} \times 1000\pi$

$= \underline{\underline{1008 \text{ rads/sec}}}$

3/ (a) The main issue is the specific magnetic loading: This relates directly to the terminal voltage in a large machine where the leakage inductance & resistance are small. ∴ $V \propto \omega \bar{B}$ so to keep $\bar{B}$ constant $\Rightarrow V \propto \omega$.

Over excited motor phasor diagram.



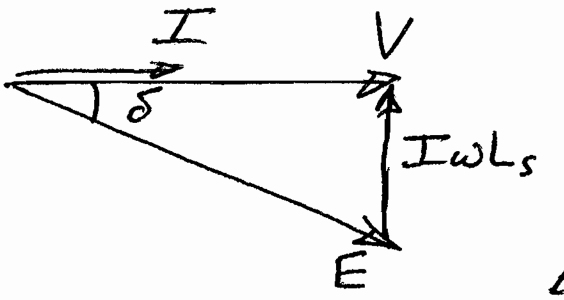
For maximum Torque per amp.

$$T\omega_s = 3VI\cos\phi$$

$$T = 3\frac{V}{\omega_s} I \cos\phi \quad \therefore \cos\phi = 1$$

ie. unity power factor

eg.



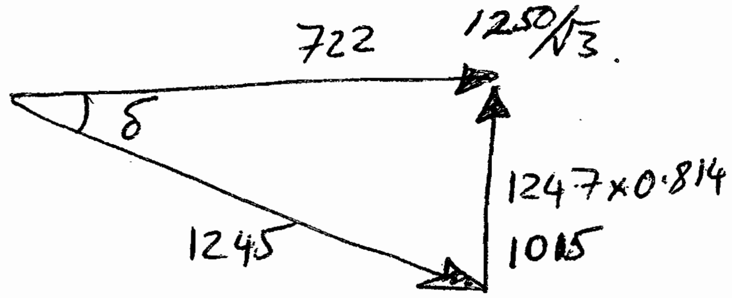
so E must be adjusted.

$$E = \sqrt{V^2 + I^2\omega^2 L_s^2}$$

3 ~~(a)~~ (b) ~~[illegible]~~ Ratings:

1250 V , 1400A . 2.7mH . 48 Hz . 2.7MW 0.9pf leading.

Excitation at full load. upf.



$$\frac{2.7M}{1250\sqrt{3}} = I$$

$= 1247 A.$

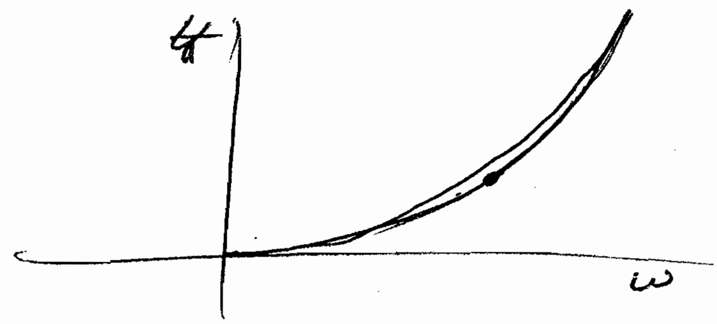
48 Hz 2.7mH

$\Rightarrow 2.7m \times 2\pi \times 48$

$= 0.814 j \Omega.$

~~Same speed~~ Half speed ~~Full~~

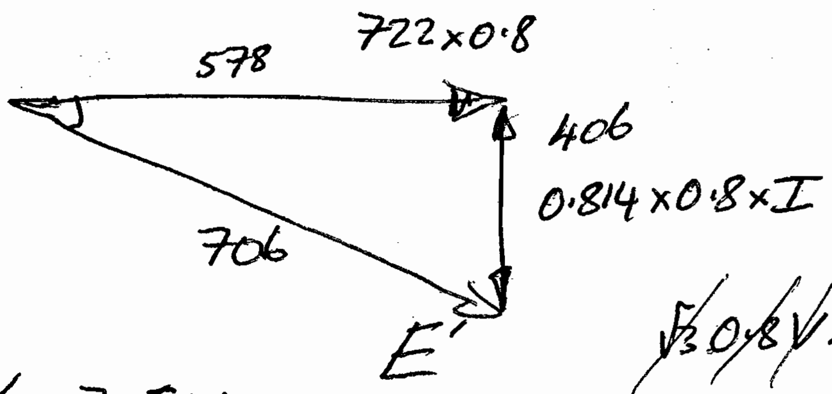
~~1/8 Torque~~



~~125~~

80% speed

50% Torque.



~~$\sqrt{3}\, 0.8 V \times I = \sqrt{3} V \times 1247 \times 0.5 \times 0.8$~~

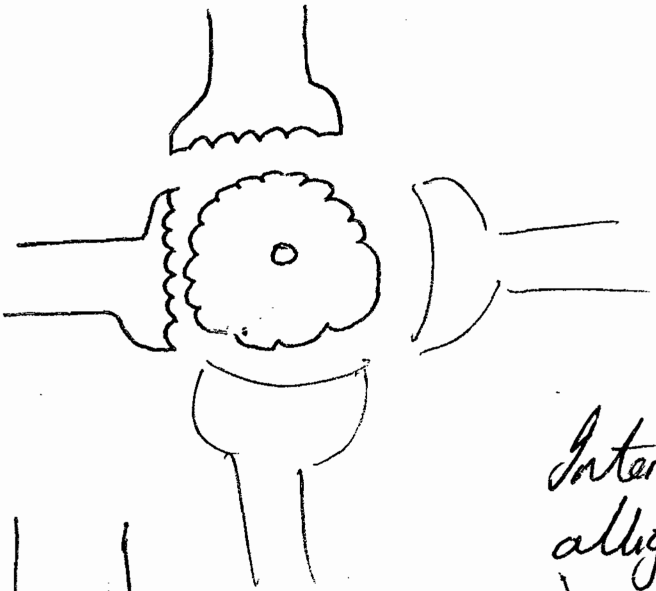
$I = 1247 \times 0.5 = 624A$

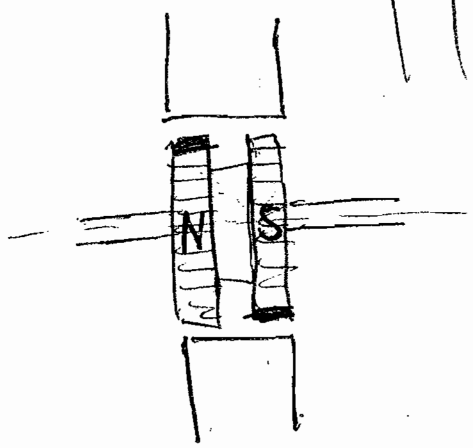
$E' = 706V$

3 (c) A P.M solution could offer a more efficient drive, with no rotor excitation. A gearbox means that a motor speed which is high may be used, making the motor much smaller.

A sinusoidal scheme has smooth torque and no vibrations. The control electronics can be a simple inverter. The trapezoidal scheme needs fast changing currents ~ not easy on big motors.

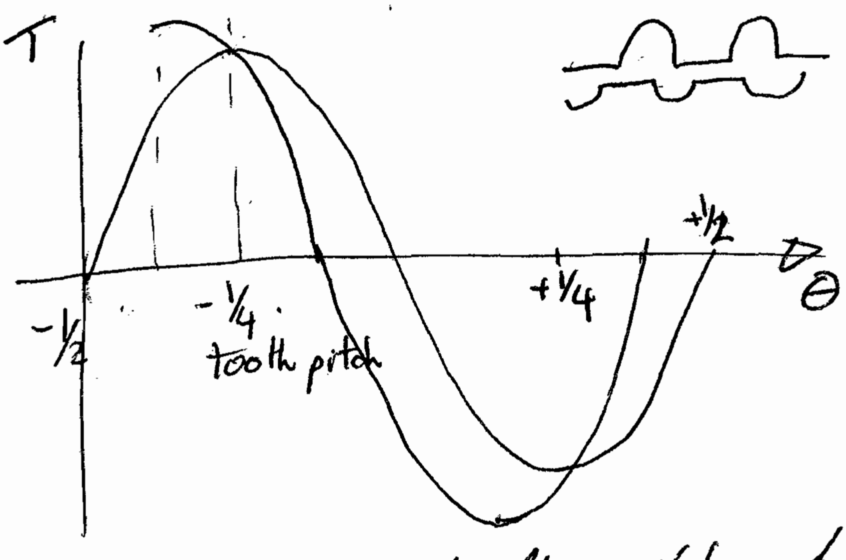
4 (a) 2 stack 2 phase





Internal magnet, axially alligned.
Teeth on the rotor and on the stator poles.
2 sets of windings.

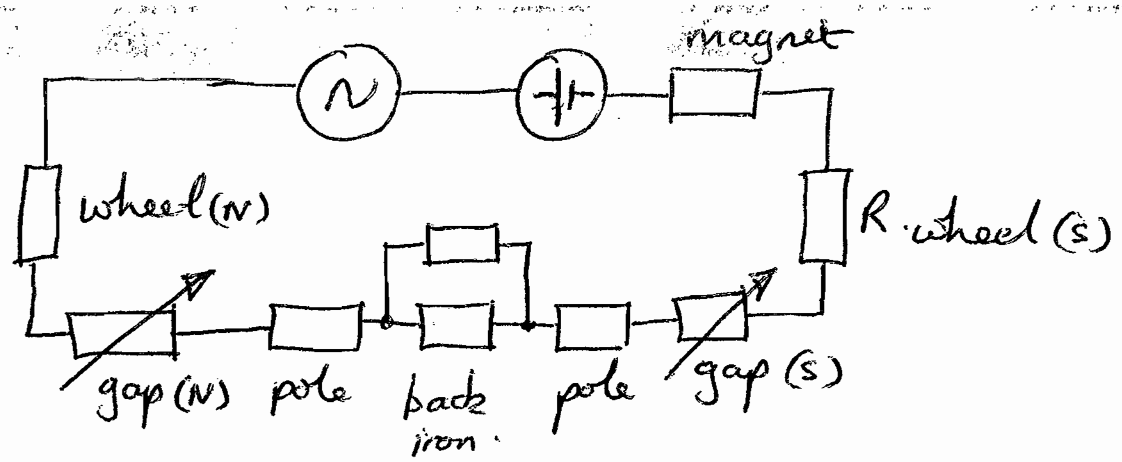
(b)



(4 steps gives one tooth pitch rotation.)

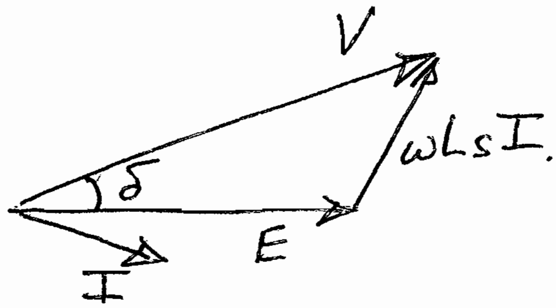
2 phase excitation moves the peak & increases the torque. Peak moves 1/8 of a tooth pitch, because the other phase gives a curve $\frac{1}{4}$ tooth pitch away

4 (c)



The torque maybe calulated using reluctance & energy stored in the gap.

(d)



$$T = \frac{1}{\omega_s} \frac{VE}{\omega L_s} \sin\delta$$

$\therefore \hat{T}$ when $\delta = 90°$

$E \propto \omega$ due to the permanent magnets.

$$\hat{T} = \frac{1}{\omega_s} \cdot V \cdot \frac{k\omega}{\omega L_s} = \frac{1}{\omega_s} \cdot \frac{Vk}{L_s}$$

$$\hat{T} \propto \frac{1}{\omega_s}$$