Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2012-13 (2.0 hours)

EEE6140 Machine Design 6

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. A 3-phase cylindrical electrical machine has 2p poles and Z total series number of conductors. The rotor diameter and axial length are D and L, respectively. Assuming full-pitched windings,

a. Show, both theoretically and graphically, how to calculate the back-emf for an ideal brushless AC machine from the airgap field distribution. **(8)**

b. From the back-emf, show that the corresponding torque density for a brushless AC machine is proportional to the magnetic loading and the electric loading. **(7)**

c. What are the major design factors that will limit the torque density, and why? **(3)**

d. What are the ideal back-emf and current waveforms for brushless DC and brushless AC machines? If the waveforms are non-ideal, what are the consequences? **(2)**

2. A 3-phase, surface-mounted permanent magnet, internal rotor brushless machine has 10 rotor poles and 12 stator slots, and all the teeth are wound, Figure 1(a):

a. Based on the coil mmf vectors, determine the coil connections for each phase. **(7)**

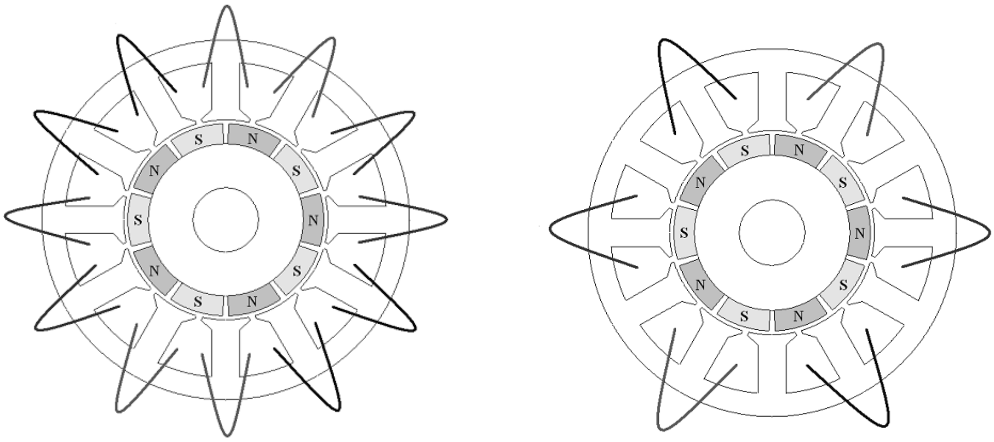
b. Derive expressions for the winding pitch factor and the winding disposition factor. **(7)**

c. If the airgap flux density distribution is given by:

$$B = 0.7\sin\theta + 0.2\sin 3\theta + 0.1\sin 5\theta + 0.08\sin 7\theta$$

calculate the 5th and 7th back-emf harmonics as a percentage of the fundamental back-emf. **(4)**

d. What are the major differences between the machine in which all the teeth are wound, Figure 1(a), and the machine in which only alternate teeth are wound, Figure 1(b)? **(2)**



(a) All teeth wound (b) Alternate teeth wound

Figure 1 12-slot/10-pole machines

3. **a.** Figure 2 shows a planar electromagnetic plunger. Calculate the winding inductance per-unit length, specifying any assumptions which are made. (full marks will not be given if the assumptions are not listed)

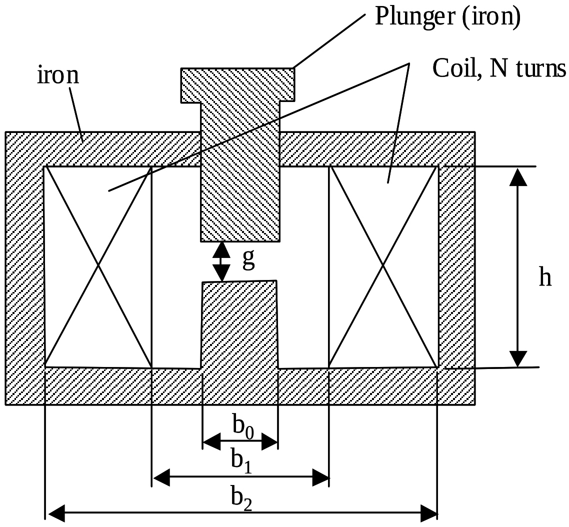


Figure 2

g=2mm, h=20mm, b_0=6mm, b_1=10mm, b_2=20mm, number of turns on coil=100, $\mu_0 = 4\pi \times 10^{-7}$ H/m. **(10)**

b. Figure 3 shows a magnetic circuit having a permanent magnet and a coil in series. Calculate the winding inductance per unit length, assuming that leakage flux outside the iron circuit can be neglected and the formulae derived in (a) may be utilised. **(8)**

c. Explain why in large electrical machines, the slot depth is often very big and open-slots are usually employed? **(2)**

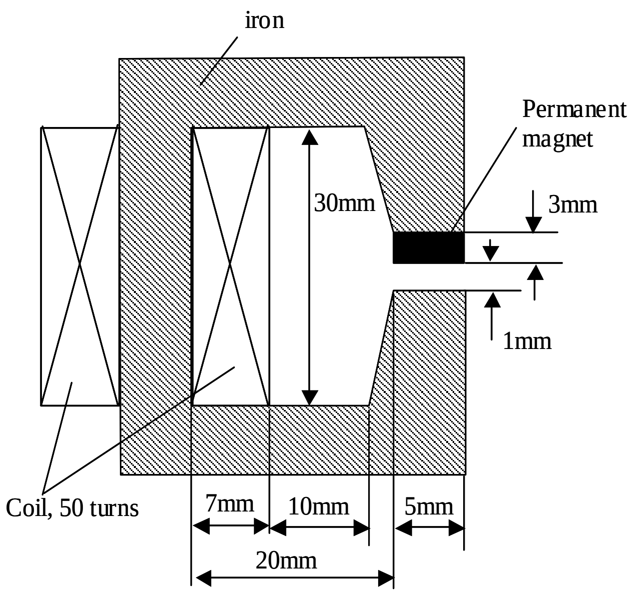


Figure 3

4. **a.** From the expression of Lorenz force, show that the torque density of a cylindrical electrical machine can be expressed in terms of the magnetic and electric loadings, B and Q, respectively. List the major assumptions which you make in the derivation. **(5)**

b. Derive an expression for estimating the airgap flux density in a permanent magnet brushless machine having an interior magnet rotor with circumferentially magnetized magnets, such as that shown in Figure 4. Explain why the airgap flux density may be higher than the magnet remanence.

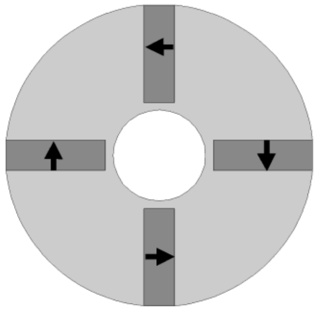


Figure 4 Typical interior magnet rotor with circumferentially magnetized magnets. **(6)**

c. Neglecting all leakage flux and fringing effects, show that when a magnet is required to produce a specific flux density B_g in an airgap of length L_g and an area A_g, it is possible to minimize the magnet volume required by operating it at its maximum energy product working point $(BH)_{max}$. Explain why this design approach for the magnet is rarely adopted in practical electrical machines. **(6)**

d. Explain how the iron losses affect the machine design and how their influence on high speed machine design can be minimised. **(3)**

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