Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2007-2008 (2 hours)

Machine Design 3

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.** Based on the coil emf vectors, determine the coil connections for a 3-phase, 9-slot, 10-pole permanent magnet motor which has a non-overlapping concentrated windings. **(6)**

b. Derive an expression for the coil inductance per-unit length, for a slot shown in Figure 1, specifying any further assumptions which need to be made (Full marks will not be given if the assumptions are not specified)

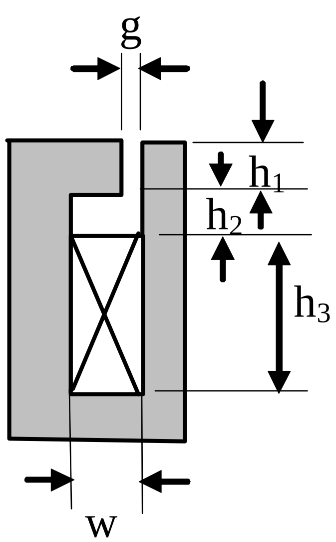

Figure 1 (Number of turns in the slot is N)

(10)

c. Show how winding pitching and distribution affect the winding inductance. **(4)**

2. **a.** For a permanent magnet brushed DC motor, making appropriate approximations, derive the torque constant K_T and the EMF constant K_E. (full marks will not be given if the appropriate approximations are not specified). **(6)**

b. Sketch typical torque-speed characteristics of a brushed DC motor when supplied from different DC voltages. For a given motor, what limits the maximum torque which can be achieved and why? **(5)**

c. Explain, with the help of a diagram, the reversible and irreversible demagnetisation phenomena in NdFeB magnet when the temperature is increased from room temperature to an elevated temperature and then reduced to the room temperature again. **(6)**

d. Explain why the irreversible demagnetisation, which is caused by the temperature rise in rare-earth magnets, is usually much more serious than that in ferrite magnets? **(3)**

3. **a.** Assuming that the airgap field distribution is uniform under the full magnet pole-arc, derive the torque equation for a single-airgap, slotless, axial-field permanent magnet brushless motor and show that the axial length for an axial-field motor can be made very small. **(8)**

b. Show how the torque equation would be modified if the airgap field distribution is still uniform under the magnet but the pole-arc to pole-pitch ratio is equal to 0.8. **(1)**

c. What is the torque equation if the airgap field distribution is sinusoidal? **(1)**

d. If the outer diameter is fixed and the electric loading is maintained constant at the inner diameter, derive the optimal ratio of the inner diameter to the outer diameter for maximum torque density. **(6)**

e. What are the most significant three differences between axial-field and radial field motors? List three major problems in axial field motor. If the motor operates as a 120 electrical degree conducting brushless DC drive, how this will affect the electrical loading and torque expression? **(4)**

4. **a.** Derive general expressions for the winding pitch-factor, K_p, and the distribution-factor, K_d, for both fundamental and nth harmonic emf components. **(7)**

b. One popular sensorless technique is based on the detection of the 3rd harmonic emf waveform. However, when it is employed to drive a 4-pole, 6-slot motor, it is found that the drive does not work. Explain why and show theoretical evidence to support your explanation. **(5)**

c. Derive general expressions for the winding inductances for a three-phase winding in a cylindrical electrical machine. **(8)**

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