Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2006-2007 (2 hours)

Modelling of Electrical Machines 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.** Draw the Kron primitive equivalent of a single-phase induction motor, labelling all currents and voltages according to the accepted conventions **(3)**

b. Starting from the Kron primitive equivalent of a single-phase induction motor, derive the steady-state terminal voltage equations and hence an equivalent circuit for operation with a sinusoidal AC supply **(12)**

c. Describe 3 methods which are employed to start single-phase induction motors, including where appropriate, representative torque speed curves **(5)**

2. **a.** Draw the general form of the unconnected Kron primitive machine, labelling all currents and coil voltages according to the accepted conventions. Derive the general form of the voltage matrix equations, leaving all rotational terms in the appropriate G coefficients **(4)**

b. Draw the Kron primitive equivalent of a series universal motor, and derive voltage equations for steady-state operation on (i) a DC supply and (ii) a sinusoidal AC supply **(4)**

c. A 2-pole, uncompensated, series universal motor produces a torque of 0.25Nm at a speed of 11,000 rpm when drawing 1.44A from a 240V DC supply. Calculate the resistance of the machine, the winding loss and its efficiency at this operating point (You may neglect iron losses in this particular case) **(4)**

d. The same universal motor is connected to a 240Vrms AC 50Hz supply. For the same output torque of 0.25Nm, the machine operates with a power factor of 0.84 lagging. Calculate the speed in rpm at this operating point (again neglect iron losses) **(4)**

e. Draw the Kron primitive equivalent of one type of compensated universal motor. Describe the basic principles of compensation with the aid of phasor diagrams for uncompensated and compensated operation (there is no need to mathematically derive voltage equations for a compensated machine) **(4)**

3. A 3-phase switched reluctance machine has 12 stator teeth and 8 rotor teeth. The stator and rotor cores are manufactured from Cobalt Iron. Each phase consists of 4 series connected coils. The measured variation in the flux-linkage of one phase with rotor angular displacement is shown in Figure 3 for a range of phase currents from 1A to 8A in 1A increments (Note:an angular displacement of 22.5° corresponds to a rotor tooth being fully-aligned with the phase)

a. Calculate the maximum induced emf in one phase of the machine at a current of 4A and a rotational speed of 3000rpm **(3)**

b. Using the information in Figure 3, plot flux-linkage versus current characteristics for rotor angular displacements of 7.5° and 22.5°, and hence calculate the average torque produced by the machine for a phase current of 5A for an excursion between these two angular displacements **(9)**

c. Sketch two dynamic flux-linkage versus current trajectories for a typical switched reluctance machine operating from a constant voltage source in motoring mode (sketch one for the interval up to the point of commutation and another for interval following commutation). Label the various energy changes which occur **(5)**

d. What factors influence the shape of the flux-linkage versus current characteristics under dynamic conditions and why is the applied voltage usually switched off prior to full alignment of the rotor and stator teeth when operating dynamically? **(3)**

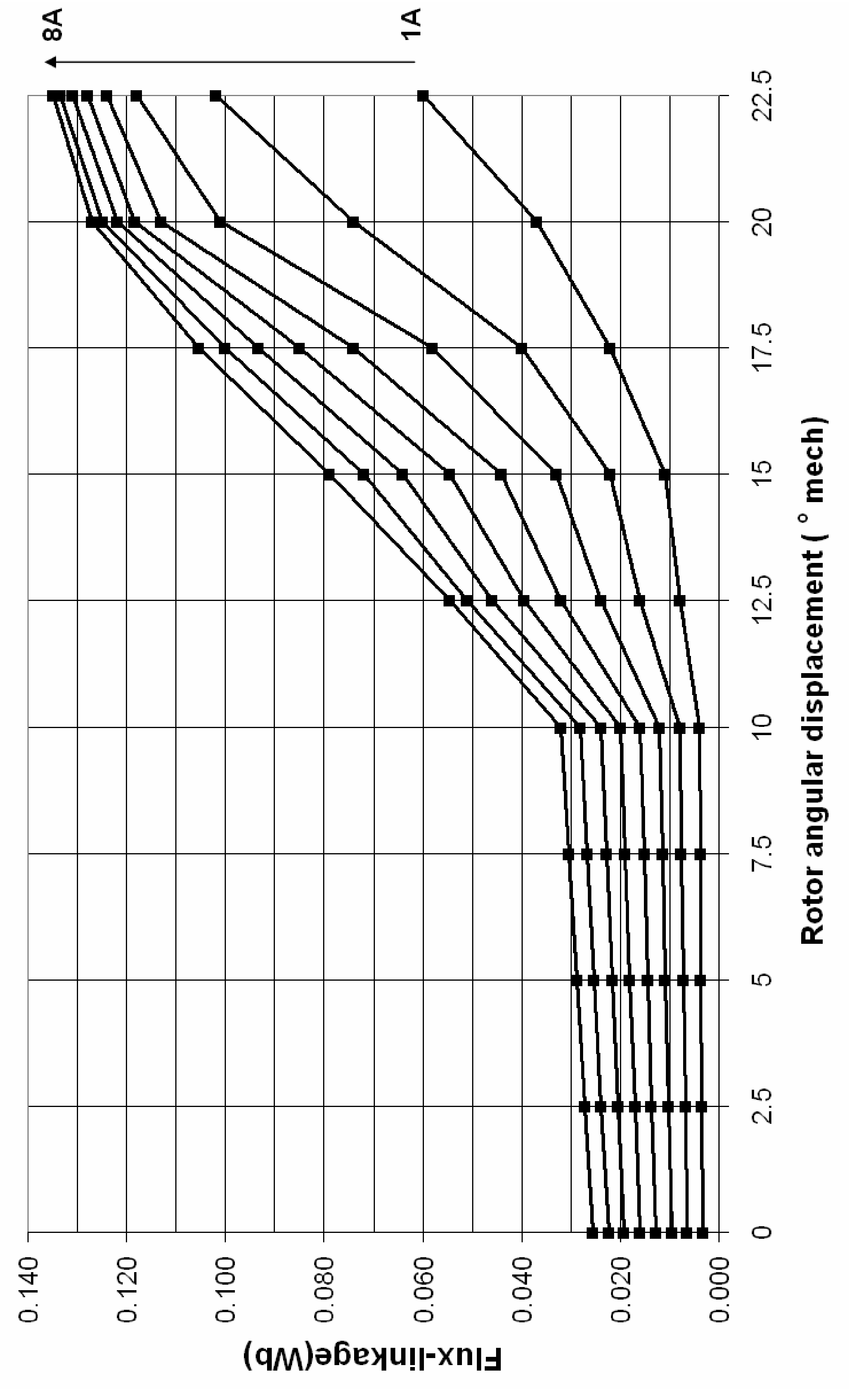

Figure 3 - Measured flux-linkage versus angular displacement characteristic at a range of currents for one phase of a 3-phase, switched reluctance machine with 12 stator teeth and 8 rotor teeth

4. Figure 4a shows a cross-section through a single phase, permanent magnet linear actuator. It consists of an E-core iron stator which is wound with a single coil, and an armature with two permanent magnets and an iron core

The actuator was initially designed to operate with a linear displacement range of ±8mm, over which it produces an essentially constant force for all currents up to its maximum rating of 5A. However the actuator's manufacturer has received a request for it to be used in a valve control system with a displacement of ±14mm. Figure 4b shows the measured flux-linkage versus displacement for this extended displacement range. (Note: The flux linkage variations of Figure 4b are not sinusoidal)

a. The actuator is used with a 28V DC voltage supply. Using the information in Figure 4, estimate the maximum velocity which the actuator could achieve over the displacement range ±8mm when connected to this supply (you may neglect the influence of any inductive and resistive voltage drops) **(4)**

b. Calculate the incremental self-inductance of the actuator at displacements of 0mm and 14mm, in both cases for current values of 1A and 5A (i.e. 4 values of inductance in total). Give a physical explanation for any differences in the values you calculate **(3)**

c. Plot flux-linkage versus current characteristics for linear displacement of 0mm, 8mm, 12mm and 14mm (i.e. 4 curves in total) **(6)**

d. Using the information contained in the flux-linkage versus current characteristics which you have drawn in part (c), calculate the force produced by the actuator at a current of 5A for an excursion between 0mm and 2mm **(2)**

e. Using the same method calculate the force produced by the actuator at a current of 5A for an excursion between 12mm and 14mm. Explain the sources of any difference in force compared to that calculated for 0mm to 2mm displacements **(5)**

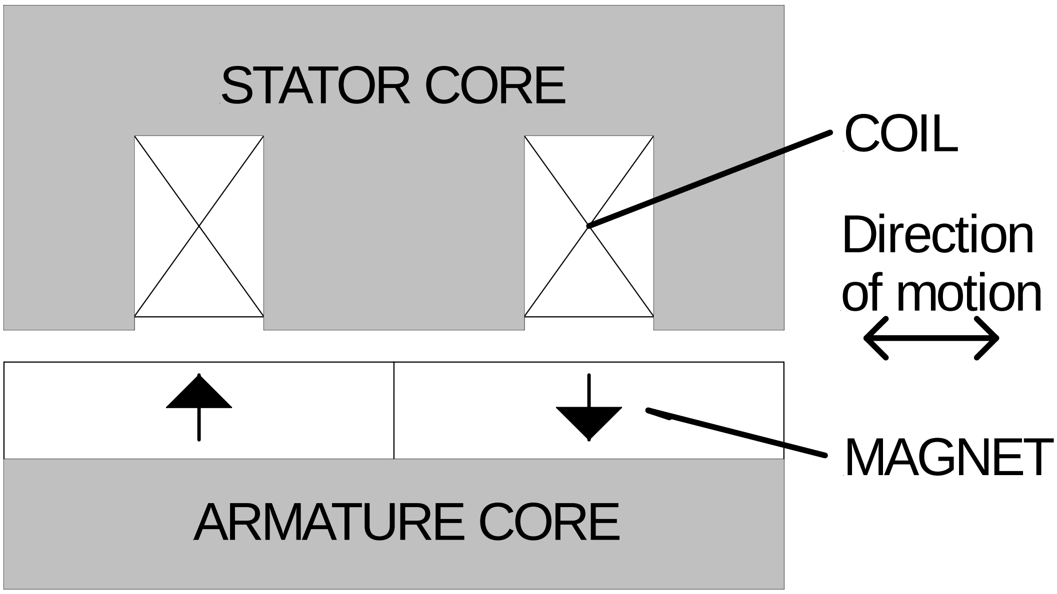

Figure 4a - Schematic cross-section through a single-phase permanent magnet linear actuator (displacement shown corresponds to 0mm)

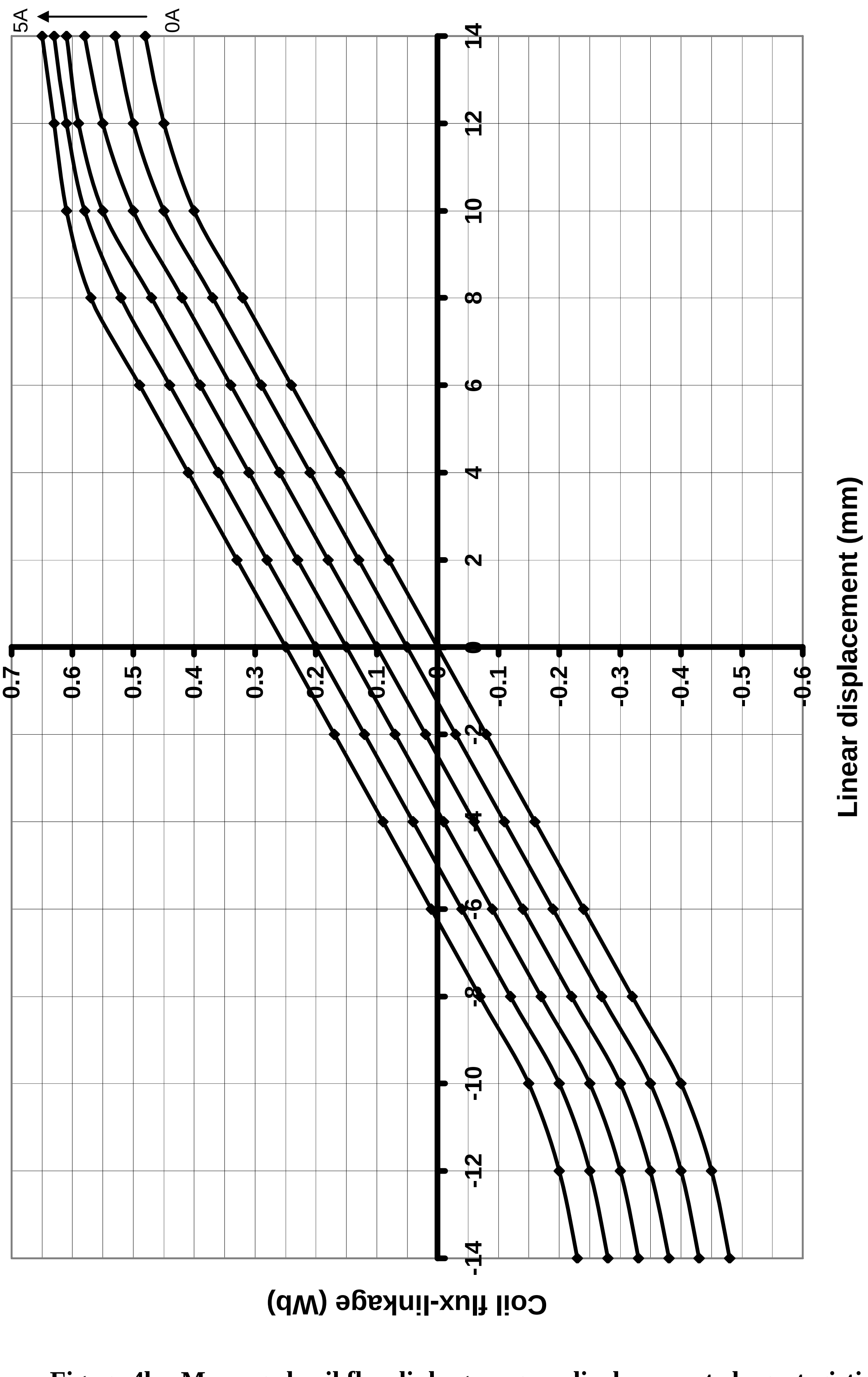

Figure 4b - Measured coil flux-linkage versus displacement characteristic for the actuator of Figure 4a

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