Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2007-2008 (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 general form of an unconnected Kron primitive machine and show the general form of its voltage matrix equations (you may leave all rotational terms in their G coefficient forms) **(4)**

b. A 2-pole series connected universal motor has a total self inductance measured at the terminals of 0.12H and a total resistance measured at the terminals of 6Ω. When connected to a 200V DC voltage supply, the motor rotates at 16,000rpm, drawing an input power of 800W. The same machine is then connected to a 230V (rms), 50Hz sinusoidal AC supply and provides the same torque to the mechanical load as that produced on the 200V DC supply.

Calculate the following:

i) The torque produced by the motor at 16,000rpm when connected to the 200V DC supply (you may neglect any iron loss in the machine)

ii) The rotational speed achieved when connected to the AC mains supply

iii) The power factor of the motor when connected to the AC mains supply **(7)**

c. In order to improve the performance on the AC supply the same universal motor is equipped with an additional inductive compensating coil. Draw the Kron primitive equivalent of this inductively compensated machine. **(2)**

d. Sketch representative phasor diagrams for both the uncompensated machine and the inductively compensated motor when connected to a sinusoidal AC supply, taking care to label the various phasors. **(3)**

e. The inductively compensated machine is connected to the same 230V (rms), 50Hz sinusoidal AC supply and provides the same torque to the mechanical load as that produced on the 200V DC supply at 16,000rpm. Assuming that the q-axis rotor coil and the d-axis stator coil have the same self inductance of 0.06H and that ideal compensation is achieved, calculate the speed at which the inductively compensated motor rotates and its power factor at this operating point. **(4)**

2. **a.** Using an appropriate diagram, briefly describe the steps involved in transforming the actual physical form of a three-phase non-salient induction motor to its Kron primitive equivalent (***there is no need to include mathematical derivations, brief descriptions of the purpose of each transformation will be sufficient***) **(4)**

b. Starting from the Kron primitive equivalent of a non-salient three-phase, induction motor, derive the voltage equations and a corresponding equivalent circuit for steady-state operation with a sinusoidal AC supply. **(8)**

c. A four-pole, non-salient, star-connected three phase induction motor for 230V (rms phase to neutral voltage) 50Hz mains operation has the following equivalent circuit parameters for one phase:

Stator resistance= 0.23Ω

Referred rotor resistance = 0.12Ω

Stator leakage reactance = 0.60Ω

Referred rotor leakage reactance = 0.25Ω

Magnetising reactance = 28Ω

When operating at a slip of 1470rpm, calculate the magnitude of the input phase current, the power factor and the total electromagnetic output torque produced by the machine at this operating point. **(8)**

3. Figure 3.1 shows a schematic representation of a single-phase linear reluctance actuator which is used in an electronic controlled security lock. The armature is drawn into alignment when current is passed through the coil. With no current in the coil, the actuator is forced back into the un-aligned position by the action of a mechanical spring. The armature moves 10mm between the unaligned and aligned positions shown in Figure 3.1. The coil has 200 turns.

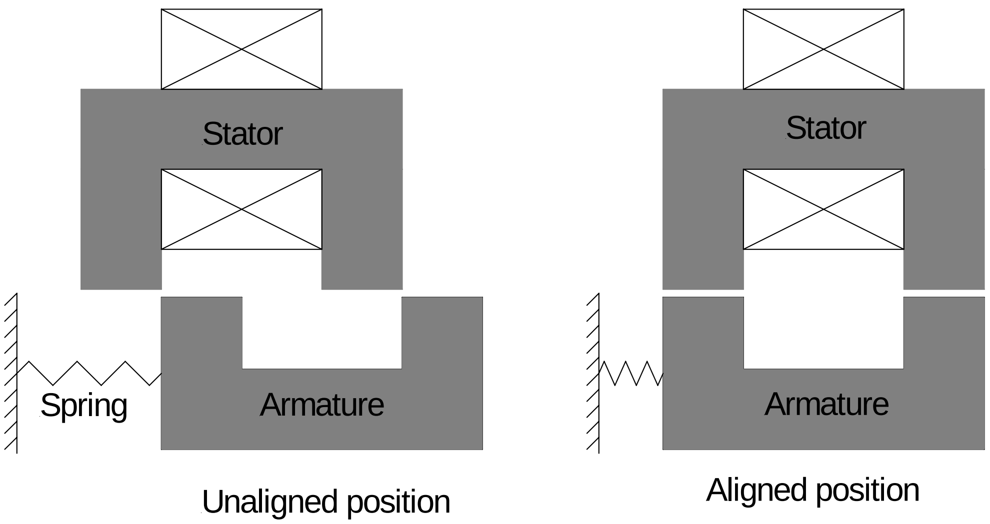


Figure 3.1 Schematic of a single-phase linear reluctance actuator

Figure 3.2 shows a series of measured flux-linkage versus current characteristics for linear displacements between the unaligned and aligned positions (with equal 2mm increments between characteristics)

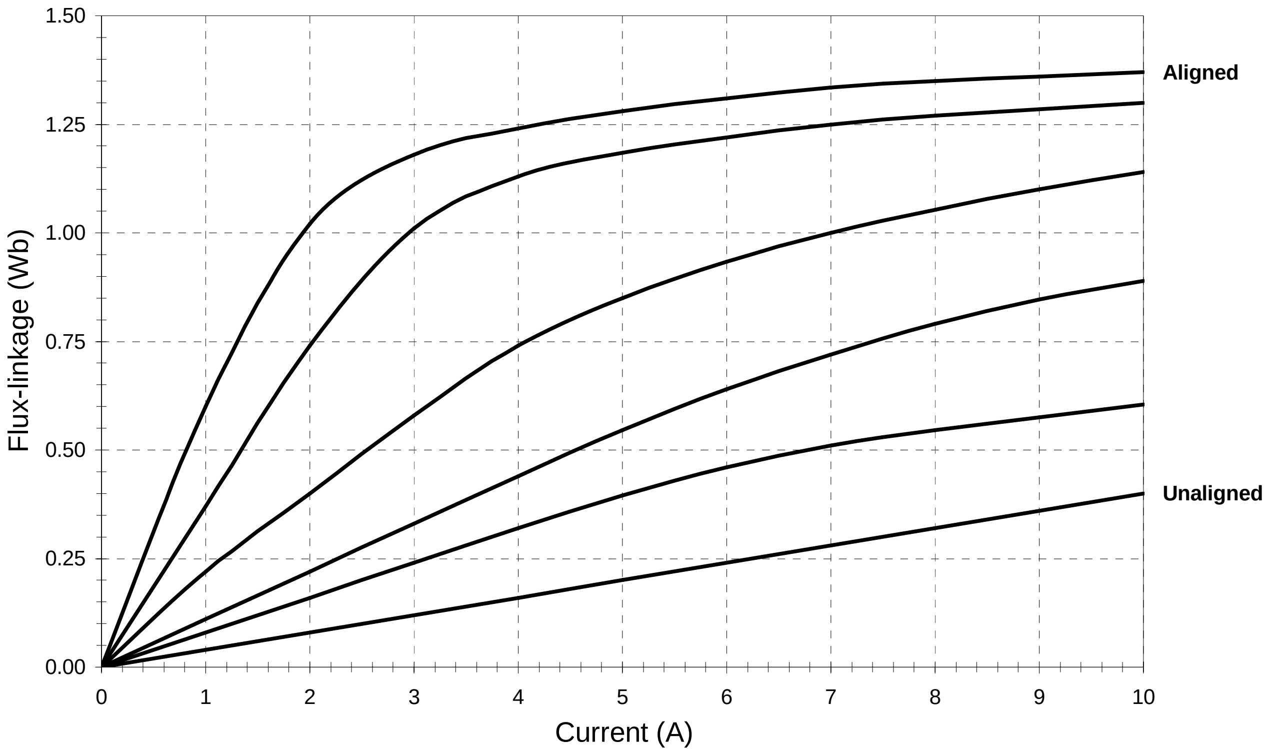


Figure 3.2. Measured flux-linkage versus current characteristics for linear displacements between the unaligned and aligned positions for the actuator of Figure 3.1

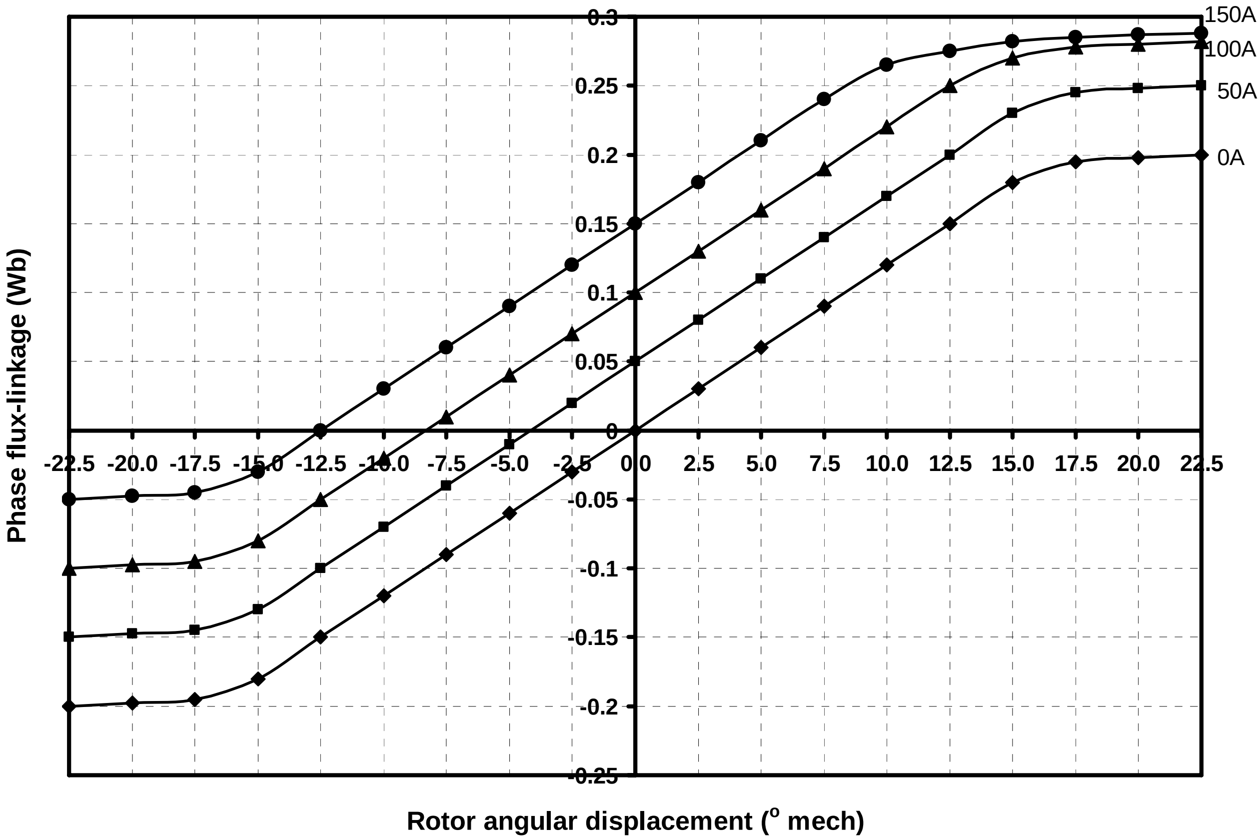
a. Calculate the average forces produced by the actuator over its full 10mm stroke for DC currents of 2A and 5A **(6)**

b. By plotting a corresponding flux-linkage versus armature displacement characteristic for a current of 5A (using the graph paper provided) estimate the magnitude of the induced emf in the coil at an armature displacement of 5mm from the un-aligned position if the armature is moving at 1.4 m/s at this displacement. **(6)**

c. In practice, the device shown in Figure 3.1 is operated dynamically from a constant voltage source, with the applied voltage being removed from the coil when the armature has moved through approximately 75% of the full stroke. Sketch a typical dynamic flux-linkage versus current trajectory for the period up to removal of the applied voltage and a separate trajectory for the remainder of the stroke, taking care in each case to shade and define any components of energy which may be of interest (these two trajectories need only be representative sketches in your answer book and not trajectories on graph paper with the same scaling as Figure 3.2). **(4)**

d. The stator and armature core materials saturate at a flux density of approximately 1.4T. Using the flux-linkage versus current characteristic for the aligned position, estimate the length of the airgap between the stator and the armature. **(4)**

4. **a.** Figure 4.1 shows the measured variation of flux-linkage with rotor angular displacement of one phase of a non-salient, three-phase permanent magnet brushless machine for various levels of DC current between 0A and 150A (in each case the DC current was present over the full excursion of angular displacement). This machine has 12 stator teeth and 8 rotor poles. The machine is normally operated in brushless DC mode.



a. Calculate the magnitude of the 'flat top' of the nominally trapezoidal open-circuit induced emf in one phase of the machine at 8000rpm. **(3)**

b. The machine is operated in brushless DC mode with 120° (electrical angle) six-step square wave currents. By plotting appropriate Ψ-i curves on graph paper, estimate the average torque produced by the entire machine for phase currents having flat-top values of 50A and 150A, noting any interesting behaviour in terms of their relative magnitudes. **(8)**

c. Calculate the phase inductance of the machine at rotor angular displacements of 0^o and 90^o and currents of 50A and 150A (i.e. four values of inductance in total) and comment on any differences between the calculated inductances **(3)**

d. The mechanical airgap in this machine is 1.0mm and each phase has 800 series turns (i.e. 200 per coil). Listing assumptions that you make, estimate the thickness of the rotor magnet in the direction of magnetisation if the stator core begins to saturate at a flux density of 1.6T (You may assume that the relative permeability of the magnet is 1.0) **(6)**

GWJ / ZQZ