Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2013-14 (2.0 hours)

EEE305 Machine Design

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.** Derive the expression of torque of a cylindrical electrical machine as a function of the electrical loading Q, the magnetic loading B, the rotor diameter D and the length L. **(4)**

b. Derive the expression of torque of an axial flux machine, shown in Figure 1, as a function of the electrical loading Q, the magnetic loading B, the inner and outer diameters D_i and D_o, respectively. Describe main differences between a radial flux machine and an axial flux electrical machine.

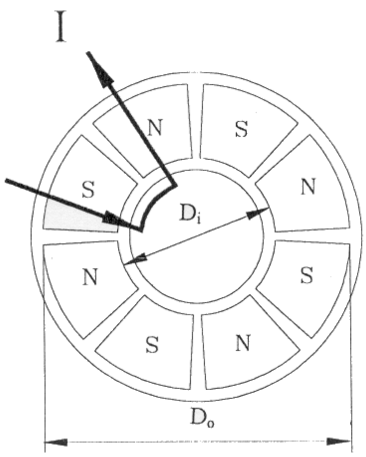

Figure 1 Rotor of axial flux machine **(7)**

c. Assuming the radial dimensions of the machine, shown in Figure 2, are increased by a factor of K, determine the relationship between the increase in electrical loading Q and the factor K. The slot number, area and current are N_s, A_s and I_s, respectively; D_1, D_2, D_3 are the inner diameter of stator, the diameter of slot bottom and the outer diameter of stator, respectively; h and w_t are the slot depth and the tooth width, respectively; and k_p and J_s are the slot filling factor and slot current density (constant), respectively. **(5)**

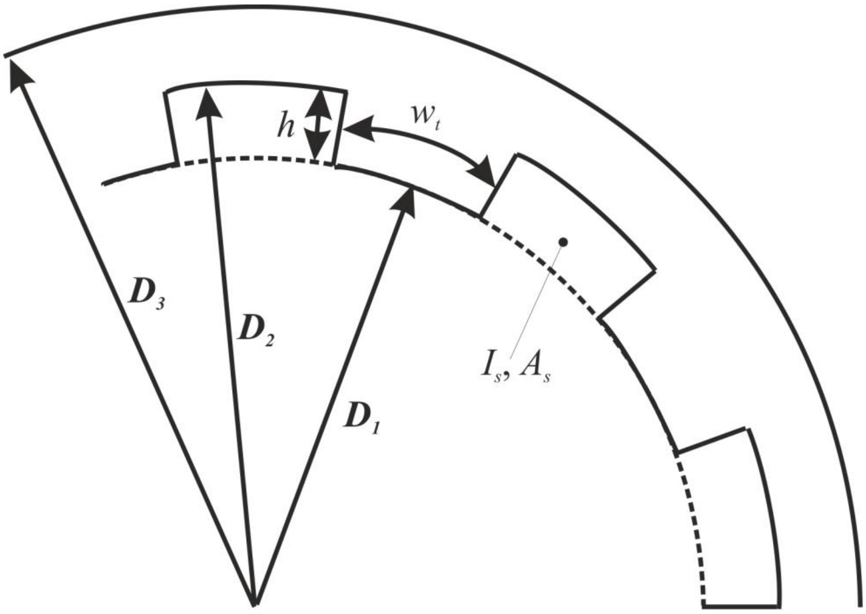

Figure 2 Stator of radial flux machine

d. What are the major design factors that will influence the electrical loading Q and the magnetic loading B? **(4)**

2. **a.** The magnetic circuit, shown in Figure 3, which has an airgap with a length l_g and area A_g, is excited by a permanent magnet with a length l_m and an area A_m, a remanence Br and a relative recoil permeability μ_r, and a coil with N turns and current I. When current $I = 0$, calculate the open-circuit airgap flux density. Describe the methods which help increase the airgap flux density and discuss their limitations. List all the assumptions that are made in the derivations.

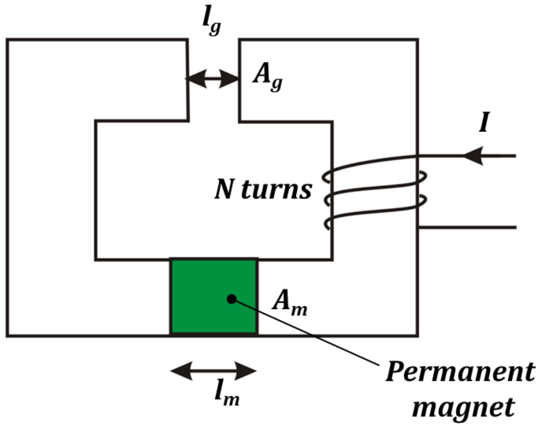

Figure 3 Magnetic circuit **(8)**

b. Derive the relationship between the magnet volume and the air-gap volume. Show graphically when the maximum energy product in magnets is achieved. **(4)**

c. Now $I \neq 0$, draw the demagnetization curve of the magnets and calculate the minimum magnet length to avoid irreversible demagnetization. **(4)**

d. Show graphically the difference between the reversible and irreversible demagnetizations. Explain the influence of temperature on the irreversible demagnetization for both Ferrite and NdFeB permanent magnets. **(4)**

3. **a.** Derive general expressions for the winding pitch factor, K_p, and the distribution factor, K_d, for both the fundamental and the n^{th} harmonic EMF components. Explain why a short-pitched winding is often preferred in practice when compared to long-pitched winding. (Both short-pitched and long-pitched windings are distributed windings). **(6)**

b. Show that the winding skew factor can be derived using similar method as for the winding distribution factor. Explain the main advantages and disadvantages of using winding skew. **(5)**

c. Employing coil EMF vectors, determine the coil connections for a 3-phase, 12-slot, 14-pole alternate teeth wound permanent magnet machine which has a non-overlapping winding, i.e. concentrated coils, in order to obtain a maximum winding factor. **(4)**

d. Employing coil EMF vectors, determine the coil connections for a 3-phase, 9-slot, 10-pole all teeth wound permanent magnet machine which has a non-overlapping winding, i.e. concentrated coils, in order to obtain a maximum winding factor. **(5)**

4. **a.** Figure 4 shows a simple reluctance machine which consists of a stator equipped with a single coil of height h_2, a width b_2, and a number of turns N. The machine has a rotor of height h_1 and width b_0, and separated from the stator by two identical airgaps of length h_0. Furthermore, the width of the air section (unwound section) of the slot is b_1 and $b_0 > h_1$. Calculate the winding inductance per-unit length of the machine, specifying any assumptions that should be made. (full marks will not be given if the assumptions are not listed).

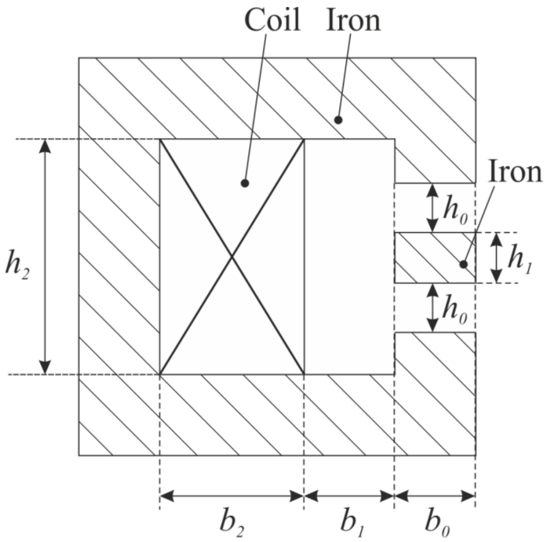

Figure 4 Simple reluctance machine **(8)**

b. The rotor shown in Figure 4 rotates to another position (90 deg. mech.), as shown in Figure 5, where the rotor surfaces are always parallel to stator teeth surfaces. Based on the assumptions given in **4.a**, calculate the winding inductance per-unit length of the machine.

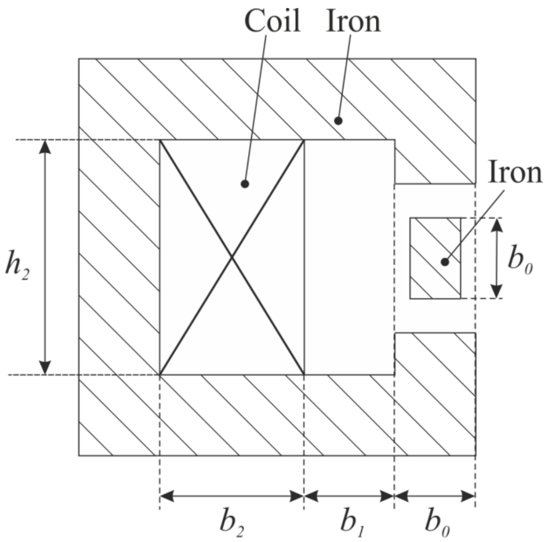

Figure 5 Simple reluctance machine **(8)**

c. Based on the results obtained from **4.a** and **4.b**, suggest possible ways to increase the winding inductance. **(4)**

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