ENGINEERING TRIPOS   PART IIA

Wednesday   7 May 2008   2.30 to 4

Module 3B4

MACHINES AND DRIVES

*Answer not more than **three** questions*

All questions carry the same number of marks

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

There are no attachments.

STATIONERY REQUIREMENTS

Single-sided script paper

SPECIAL REQUIREMENTS

Engineering Data Book

CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

1 (a) A brushless dc motor is used to drive a model aircraft propellor. It is rated at 1100 rpm per Volt, 30 A continuous loading, 42 A loading for 60 seconds and for 7-10 battery cells. Give a physical interpretation for each rating.

Give three reasons why many brushless dc motors are constructed with their rotor outside the stator of the motor, as shown in Fig. 1.   [35%]

(b) Explain carefully why the output power of a well designed machine is proportional to the volume described by the airgap dimensions and the speed of rotation. Discuss briefly the implications of this for the modern application of electric motor drives to window winders for cars or linear motion in robotics.   [35%]

(c) Discuss the application of high temperature superconducting wires to electric motor drives, paying particular attention to the volume of the machine and any other particular features arising.

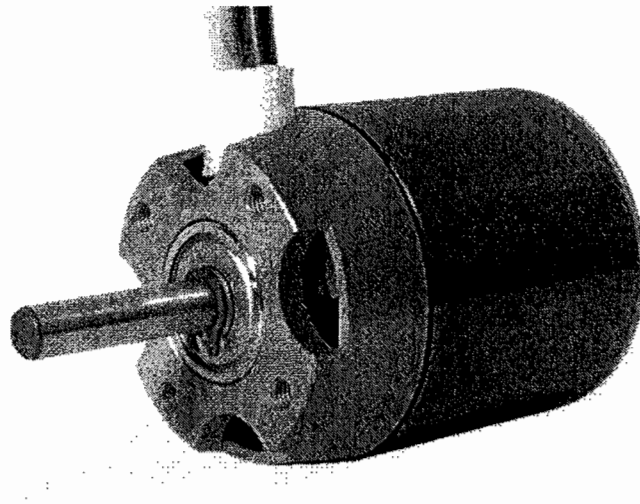Show that a superconducting induction motor is unlikely to perform well.   [30%]

Fig. 1

2   (a)   Explain carefully the meaning of the term *slip, s* when applied to induction motors, where *s* is given by

$$s = \frac{(\omega_s - \omega_r)}{\omega_s} \quad .$$

Show that the torque of a two pole three phase induction motor can be approximated by

$$T = 3V\frac{s}{R_2}I_m L_m \quad ,$$

where T is the torque, V is the applied voltage, L_m is the magnetising inductance, I_m is the magnetising current and R_2 the referred rotor resistance.   State the approximations necessary.   [40%]

Making reference to the expression for Torque, explain how a rapid change in Torque may be obtained in practice and outline such a scheme using a sketch of the principal system blocks and feedback paths.   [30%]

(b)   A mining truck climbing an incline imposes a constant torque load on the wheel motor (induction motor). For a single moderate load torque and speed, sketch two different torque speed curves for the motor that satisfy the load requirement. Making reference to the Torque expression of Part (a) or otherwise, give one advantage and one disadvantage for each curve.   [30%]

3   (a)   With regard to brushless dc drives, explain the statement, "some method of detecting the motor position is required". Hence draw the main feedback loops for a brushless dc drive using Hall sensors.   [40%]

       (b)   The torque profile for a trapezoidal brushless dc motor is shown in Fig. 2. By consideration of the profile, or otherwise, explain why the back emf waveform in such a motor is also trapezoidal.   [20%]

       (c)   Sensorless brushless dc uses the induced voltage in the floating phase. On a set of three phase voltages identify when phases are conducting or floating.

       By considering the circuit formed by two conducting phases and the three phase waveforms, suggest a method for using the floating phase voltage for timing commutation. (The star point of the motor windings is not available).

       State why sensor brushless dc drives are better when many stop starts are required?   [40%]
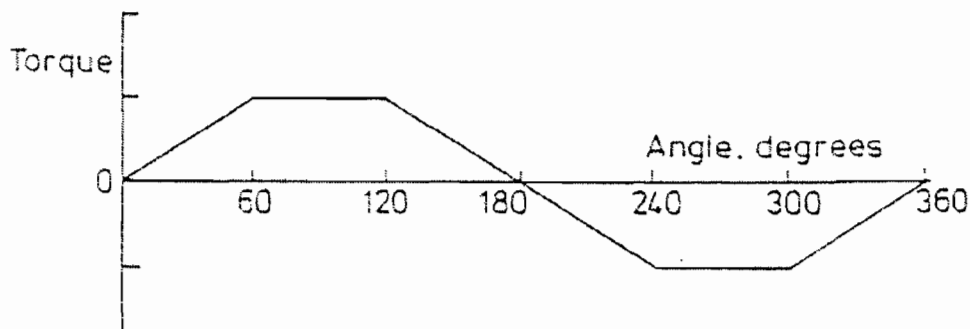

Fig. 2

4   (a)   State why the brushless dc motor and the hybrid stepper motor can be considered as closely related machines. Compose a table of differences that would assist an engineer in choosing an electric drive for their application. Your table should mention at least five issues.   [40%]

(b)   Both the brushless dc motor and the stepper motor create an induced emf E when operating at speed. Draw an equivalent circuit for a phase including the effects of the winding resistance and write down an expression for the supply voltage V.

Draw a phasor diagram for a brushless dc motor motoring at speed and a phasor diagram for a stepper motor motoring at speed.   [30%]

(c)   A new washing machine employs a three phase 6/4 (stator teeth to rotor teeth) variable reluctance motor for the main drum drive. By considering the current and voltage for one of the phase windings, draw an equivalent circuit for the phase winding and explain the physical mechanism associated with each term.

By sketching the change of inductance with time, Show that the current should be applied before the rotor pole is aligned to the stator pole for maximum torque to be obtained when operating at speed.   [30%]

END OF PAPER