is determined by the magnetization curve. Now, the emf produced by Φ_o depends on the speed : at n_1, it is

$E_1 = k_e n_1 \Phi_o$, while at n_2 it is $E_2 = k e n_2 \Phi_o$ Dividing, we get

$$\frac{E_2}{E_1} = \frac{n_2}{n_1} \qquad (4.10)$$

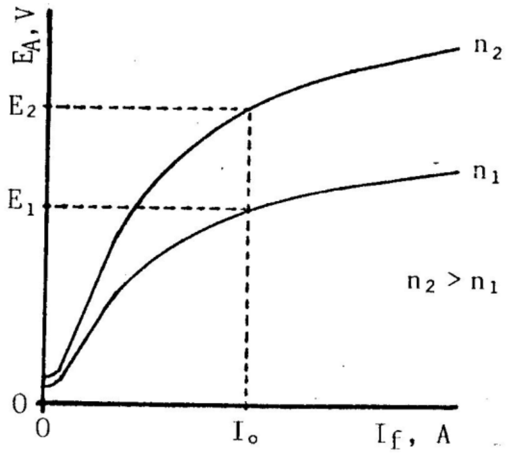

Fig. 4.9 Effect of speed on OCC

That is, at a given field current, the emfs are in the ratio of speeds, fig. 4.9. Thus, if the emf is known atone speed, it can be found at any other speed using

$$E_2 = (n_2/n_1) \cdot E_1 \qquad (4.11)$$

Where E_1 and E_2 are at the same field current. Applying eqn. 4.11 at various values of field current, the OCC at n_2 can be obtained from the OCC at n_l, fig. 4.9.

4.5 Exercises

4.1 Sketch the cross-section of a 6-pole dc machine showing armature, poles, and yoke.

Insert and mark all direct and quadrature axes. Show the main field flux distribution, including leakage.

4.2 The addition of tips to the pole increases the pole arc /pole pitch ratio; this helps improve the air gap flux density distribution and decreases air gap reluctance as explained in section 2.4.1 and fig. 2.5. Why, then, are machines designed with pole arc/pole pitch ratios not exceeding (70 -75) %?

4.3 Fig. 4.2 shows flux lines in the air gap. Complete the figure by extending the lines into the pole shoe and armature teeth. What conclusions can you make regarding flux density, and hence saturation, in teeth?

4.4 Explain how the slotting effect discussed in section 4.1 causes eddy current and hysteresis; losses in pole shoes.

4.5 a; Shunt field windings are designed for low current, ie much less than armature current. Explain why this is desirable, and how it is achieved.

b. Series field windings are designed for low voltage drop, ie much less than armature voltage. Explain why this is desirable, and how it is achieved.

4.6 Draw the connection diagram of a short-shunt compound motor, with resistors to control the currents in the shunt and series field windings.

4.7 Fig. 4.10 shows the terminal box of a dc machine, together with the terminals of a dc source and a resistor. Insert connections for each of the following cases:

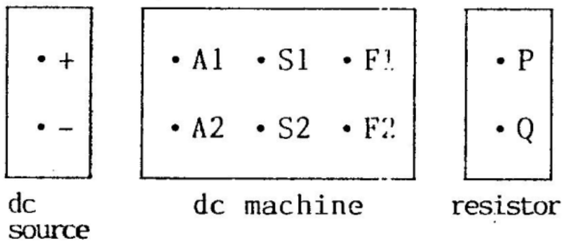

Fig. 4.10 Question 4.7

a. A separately-excited generator loaded by the resistor.

b. A shunt motor fed from the source, with the resistor used for field control.

c. A shunt motor as in part b, but rotating in the opposite direction.

d. A short-shunt compound motor fed from the source, with the resistor used to control the series field current.

4.8 Fig. 4.11 shows a pole excited by five coils, with currents as indicated by the arrows. Write the expression for the total mmf per pole in terms of the currents and turns of the individual coils.

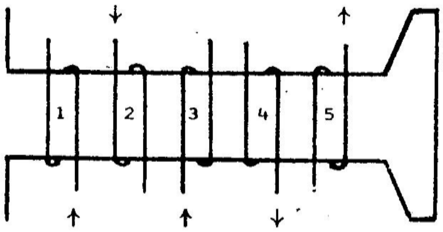

Fig. 4.11 Question 4.8

4.9 why is it not possible to measure the OCC unless the machine is connected as a separately-excited generator at no-load?

4.10 in fig. 4.8, the field current is varied by means of a series rheostat. Show how it can also be varied by means of a voltage divider across the supply.

4.11 The OCC is measured by increasing the field current in steps from zero to some maximum value, and recording the corresponding values of armature emf. If now the current is decreased from maximum to zero, the emf values will be different; why?

4.12 In a compound machine, the shunt field winding has 470 turns/pole, and the series field winding has 13 turns/pole. What current in the shunt field winding produce an mmf equal to that produced by 15 A in the series field winding?

4.13 The armature of a 6-pole dc machine is wave-wound with 46 coils and 3 turns/coil. The field winding has 630 turns/pole. the resistances of the armature and field windings are 75 mΩ and 40Ωrespectively; the brush contact drop is approximately constant at 1.5V. The OCC at 800 rpm is given in table 4.1

Table 4.1 at 800 rpm

I_f (A)	0	0.3	0.5	1.0	1.5	2	2.5	3	3.5	4	4.5	5	6	7	8	9
E_a (V)	8	28	46	94.5	143	175	195.5	211	224	234	243	252	266	277	286	295

a. Plot the OCC at 800 rpm.

b. On the same sheet of part a, plot the OCC at 600 rpm and at 1000 rpm.

c. Plot, on a different sheet, the magnetization curve in the form of fig.4.6, ie flux per pole Φ against mmf per pole M_f.

d. At 800 rpm, estimate the mmf drops in the air gap and in the iron when the emf is (i)100 V,(ii)200 V, and (iii)300 V.

e. what is the residual flux per pole Φ_r?

f. what is the air gap reluctance S_{ag}?

g. Determine the reluctance of the iron parts, S_{fe}, at the 3 emf values of part d.

h. Determine the induced emf when the field current is 5.5 A and the speed is (i)800 rpm, and (ii)1500 rpm.

i. Determine the field current when the emf is 270V and the speed is (i)800rpm, and(ii)1500 rpm.

j. If the field current is 3.8A, at what speed will the emf be(i)200V? (ii) 300V?

k. The machine is operated as a separately-excited motor at 1100 rpm; the armature terminal voltage and current are300 V and 70 A respectively. Find the field current.

l. A series field winding is added to the machine such that when the speed is 500 rpm and the shunt field current is 3 A, the armature emf and current are 150 V and 80 A respectively. Find the number of turns of the series field winding.

Table 4.2 OCC at 1200 rpm

m. The machine is operated as a shunt motor; it draws 80 A from a 220 V source. What is the speed?

4.14 An 8-pole dc machine has 266 armature conductors connected in simple wave. The armature resistance is 0.75Ωand the brush contact drop may be assumed constant at 2.5V. Each field coil has725 turns. The OCC at 1200 rpm is given in table 4.2.

I_f (A)	E_a (V)
0.0	35
0.1	105
0.2	210
0.3	315
0.4	375
0.5	412
0.6	440
0.8	482
1.0	520
1.2	550
1.5	585
2.0	630
2.5	660

a. Plot the OCC at 1200 rpm.

b. What is the flux per pole when the field current is l.3 A?

c. Find the total mmf and the mmf drops in the air gap and the iron when the flux per pole is

(i)14 mWb, and (ii)25 mWb.

d. If the machine runs at l600 rpm with the field excitation set at 0.7 A, what is the emf?

e. If the emf is 380 V at 750 rpm, what is the field current?

f. The machine operates as a generator with a constant field current of 1.4 A, and a constant

terminal voltage 0f 700 v. At what speed will the armature current be zero?

g. The machine operates as a motor at 1500 rpm with a field current of 2 A; it develops 80 Nm. Find the terminal voltage and conversion power.

4.15 The machine of question 4.14 is connected as a compound motor in long shunt, with a series field winding of 20 turns per pole.

a. The motor current is 15 A, and the shunt field current is 1 A. Find the induced emf at 1000 rpm if the compounding is (i)cumulative, and(ii)differential

b. The motor current is 20 A, and the shunt field current is l.5 A; the compounding is cumulative, and the resistance of the series field winding is negligible. If the terminal voltage is 400 V, find the speed, conversion power, developed torque, and armature copper loss.

4.16 The resistances of the armature and field windings of a series machine are 0.1 Ω and 0.05 Ω respectively. The brush contact drop is 1 V. The OCC at 400 rpm is given in table 4.3.

Table 4.3OCC at 400 rpm.

I (A)	Ea (V)
5	10.3
10	16.7
15	19.9
20	21.3
25	21.8
30	22.0

a. The machine is operated as a generator at550 rpm. If the load current is 28 A, find the load power and resistance.

b. The machine is operated as a motor from a battery whose emf and internal resistance are 14 V and 0.07 Ω respectively. Find the speed and conversion power when the motor

current is (i)12A, and (ii)24 A.

ANSWERS TO EXERCISE QUESTIONS

4.12 0.415 A**4.13**d. (i)667A.t, 0; (ii)1333A.t, 324At;(iii)2KAt, 4.1 KAt; e.0.725 mWb;f. 73.6 Kat/Wb; g. 0,17.9 KAt/Wb, 151.3 KAt/Wb; h. (i)259V; 485.6V; i. (i)6.4A; (ii)1.5A;j. (i)695 rpm; (ii)1042 rpm; k. 3.1 A;1.10 turns; m. 658 rpm.

4.14b. 26. 5 mWb; c. (i)203 At, 203 At, 0;(ii)779 At, 367 At, 412 At; d. 616V; e. 1.74A; f. 1461 rpm; g. 802V, 12.57KW**4.15**a. (i)478V; (ii)369V; b. 731 rpm, 7.1 KW, 92.75Nm, 257W**4.16**a. 698 W, 0.89Ω; b. (i)226 rpm, 124W; (ii)142 rpm, 185 W.