The accurate control of dc motors makes them suitable for servomotor duty in automatic control systems. The motors in such applications generally have small power rating (less than 1 KW), and are required to drive a load in accordance with a control signal applied to the armature (armature voltage control). They are usually constant field motors (PM or separately-excited) designed to have a low moment of inertia for quick response, and linear mechanical characteristics for accurate control, see fig. 9.20.

The flexibility of control of dc motors makes them suitable for certain heavy power applications such as lifts, cranes, and electric traction (electric trains), as well as certain drives in heavy industry. These app1icaticns can invo1ve frequent changes in speed, stops and starts, and possibly reversals. The hard characteristics of shunt motors with armature voltage control are ideal for adjustable1 speed drives, while the softer characteristics of compound and series motors are sometimes exploited in traction (locomotives)to do without different gear ratios.

9.14 Sheet ch.9

Unless otherwise stated, assume that (i) winding resistances are given at the working temperatures, (ii) the demagnetizing effect of armature reaction is negligible, and (iii)the brush contact drop is 2 volts. Some of the questions refer to the following machines and loads:

Machine M1 is a dc motor rated at 220 v, 1600 rpm, and 13.5 hp. The armature and shunt field resistances are 0.357 ohms and 55 ohms. The OCC is given in table 1 . it is known from tests that the torque due to rotational losses is approximately proportional to speed. The motor also has a series winding having 6 % of the shunt field turns and a resistance of 0.223 ohms; unless otherwise stated, assume the series winding to be disconnected.

Mac**hine M2** is a series motor whose armature and field resistances are 40 and 10 milliohms respectively. the occ is given in table 2. The brush contact drop may be assumed constant at 1v, and the rotational losses are approximately equal to 3n, where n is the speed in rps.

Machine tool load L1 has a torque-speed characteristic given by:

T = 8 + 1.7n .

fan load L2 has a torque-speed characteristic given by T = 9.6 + 0.05n2.

Table 1 OCC for M1at 1600 rpm.

Amps	volts
0.0	8
0.3	21
0.55	40
1.3	97
1.7	124
2.3	154
3.0	179
4.0	198
5.0	210
6.0	218
7.1	224
8.3	228

Table 2 OCC for M2 at 750 rpm.

Amps	Volts
0	0.0
3	2.0
5	3.5
7	4.7
10	6.45
15	8.45
20	10.1
25	11.35
30	12.35
35	12.9
40	13.4
50	13.92
60	14.2
75	14.3

1. A shunt motor runs on 250 V. the armature circuit resistance is 0.7 ohms, and the field circuit resistance is 25 ohms. For a certain load, the motor rotates at 1200 rpm and draws 100 A. (a) Find the developed torque when the motor current is 100 A. (b) find the motor current and shaft speed when the motor develops 300 Nm. (c)Estimate the no-load speed and the rate of change of speed with torque.
2. A PM motor runs from a 60 V supply, and has an armature resistance of 0.2 ohms. At no-load it draws 1.5 A and rotates at 900 rpm. The brush contact drop is 1v. (a) what is the full-load current if the full-

load speed is 750rpm? (b)find the speed regulation and developed torque when the current is 30 A. (c) A series resistor of 0.07 ohms is used to reduce speed. Find the speed regulation and current for the same developed torque obtained in part b.

3. A shunt motor runs on 400 V. the armature and field circuit resistances are 0.5 and 250 ohms. At no-load it draws 4.3 A and rotates at 1350 rpm. At full-load it draws 42.6 A. (a) Find KeΦ, the electrical losses, and the rotational losses at no-load. (b) Find the full-load speed, output horsepower, efficiency, speed regulation, and developed torque. (c)Repeat part b assuming armature reaction reduces the field by 25% with the field current kept constant (by decreasing the resistance in series with the shunt field winding). Neglecting armature reaction, find the motor speed and torque when it draws full-load current.
4. A series motor is fed from a 120 V line. its armature and field resistances are 0.3 and 0.1 ohms respectively. (a)the motor drives a certain load at 650 rpm and draws 78 A; find the developed torque. (b) with the developed torque unchanged from part a, the speed is reduced by means of a 0.6 ohm series resistor; find the speed. (c) for the same developed torque of parts a and b, what resistance is needed to reduce the speed to 450 rpm? (d) the load is changed so that the current becomes 50 A; find the developed torque and speed assuming this current is large enough to saturate the iron circuit of the motor. (e)repeat part d assuming that at a load of 78 A operation is on the linear part of the magnetization curve of the motor.
5. Machine M1 is connected in shunt and operates at rating with no external resistor in the field circuit. (a) find the rated current of the motor; also find the efficiency. (b) find the torque due rotational losses, and hence write out the equation of this torque as a function of speed.
6. Machine M1 is driven from a 220 V source, with the field supplied with 5.5 A from a separate source. (a) find the developed torque and speed when the armature current is 40 A. (b)find the armature current & speed when the developed torque is 25 Nm. (c) find the armature current and the developed torque when the speed is 1400 rpm. (d) repeat part a when the series field winding is connected in the armature circuit cumulatively. (e) repeat part d for differential compounding.
7. Machine M1 is connected in shunt with full field excitation. It operates at rated voltage. (a) neglecting the torque due rotational losses, determine the equations for the torque characteristic and the mechanical characteristic; also find the speeds at (i) no load, (ii) rated motor current, and (iii) 25%overload current. (b) repeat part a with the torque due to rotational losses included; also find the no-load current. (c) the motor is loaded by machine tool load L1; find the torque, speed, and motor current with the rotational losses (i)neglected as in part a, and (ii) included as in part b . (d) repeat part c for the fun load L2.
8. Machine M1 is connected in long shunt. The applied voltage is 220 V, and there is no external resistance in the shunt field circuit. At a line current of 60 A, find the speed, developed torque, and output power when the compounding is : (a) cumulative with no diverter; (b) cumulative with a 0.4 ohm diverter; and (c) differential.
9. Machine M1 is connected first as a shunt motor with a field control resistor of 33 ohms, then as a long shunt cumulative compound motor with the same resistor in the field circuit, and finally as a series motor. Rated voltage is applied in all cases. (a) plot on one sheet the mechanical characteristics for the three cases. (b) for each case, find (i) the speed when the load torque is 50 Nm, (ii) the load torque when the speed is 1700 rpm, and (iii) the reduction in speed when the torque is increased from 30 Nm to 90Nm.
10. Machine M1 is first connected in shunt, and then in cumulative long shunt. In both cases, operation is at rated voltage and full field. (a) plot on one sheet the torque characteristics for the two cases (up to 75 A). (b) plot on one sheet mechanical characteristics for the two cases; plot on the same sheet the torque-speed curves of the machine tool load L1 and the fan load L2. (c)use your curves to obtain the no-load speed and no-load current for each motor connection. (d) use your curves to determine the torque, speed, and current for each of the three motor connections when loaded by each of the two