

9 Testing of d.c. machines

A d.c. machine has to be tested for proper fabrication and trouble free operation. From the tests one can determine the external characteristics needed for application of these machines. Also, one can find the efficiency, rating and temperature rise of the machine. Some of the tests are discussed in sequence now.

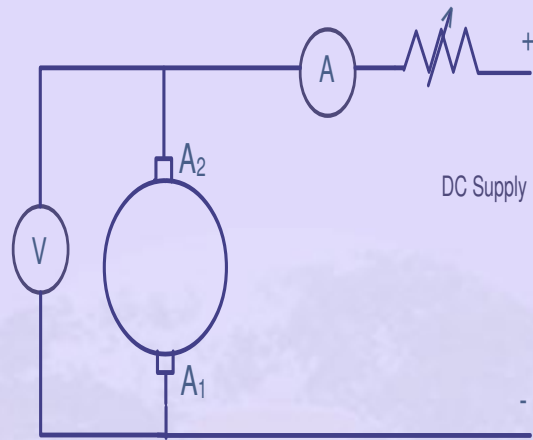
9.1 Measurement of armature resistance

Measurement of winding resistances of field windings and armature winding are performed by v-i method. Field is not excited during this test.

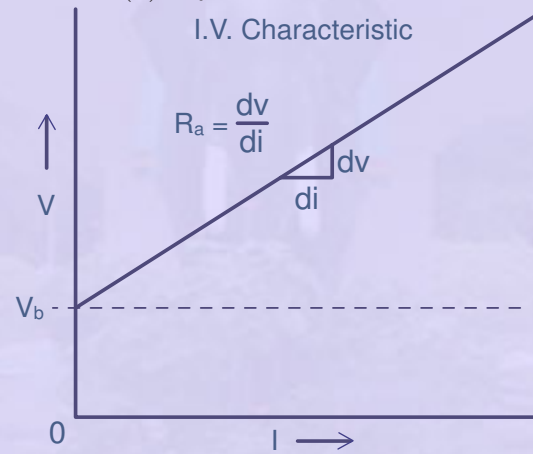
Even though any value of applied voltage can be used, the highest permissible voltage/current is chosen during the test to minimize the errors. The armature circuit consists of two resistances in series. They are armature winding resistance and resistance due to the brushes and the brush drop. The brush contact drop behaves like a non-linear resistance. To separate this from the armature circuit resistance and brush resistance a number of v-i readings are taken. An equation of $V = V_b + IR_a$ form is fitted through these test points shown graphically in Fig. 55. For large values of I the equivalent armature resistance is taken to be V/I ohm. If the value of brush drop V_b can be neglected then the armature resistance $R_a = V/I$ ohm.

9.2 Open Circuit Characteristic (OCC)

The OCC is of great value as it shows the mmf and hence the field current required to generate a given voltage at any speed, on no load. It is a graph showing the variation



(a) Physical connection



(b) Characteristics

Figure 55: Measurement of Armature resistance and Brush drop

of the induced emf as a function of excitation current, when the speed is held constant, with the load current being zero. It is also called the no-load saturation curve or no load magnetization characteristic. This is experimentally determined by running the machine as a separately excited generator on no-load at a constant speed and noting the terminal voltage as a function of the excitation current. This curve can be used to find the OCC at other speeds and also the self excited voltage when the machine works as a shunt generator.

9.3 Short circuit characteristics:(SCC)

In the case of short circuit test the armature is kept short circuited through an ammeter. The machine is demagnetized and an extremely small field current is passed through the field. The variation of the short circuit current as a function of excitation current is plotted as the SCC. The speed is to be held constant during this test also. The short circuit test gives an idea of the armature drop at any load current.

9.4 Load test

To assess the rating of a machine a load test has to be conducted. When the machine is loaded, certain fraction of the input is lost inside the machine and appears as heat, increasing the temperature of the machine. If the temperature rise is excessive then it affects the insulations, ultimately leading to the breakdown of the insulation and the machine. The load test gives the information about the efficiency of a given machine at any load condition. Also, it gives the temperature rise of the machine. If the temperature rise is below the permissible value for the insulation then the machine can be safely operated at that load, else the load has to be reduced. The maximum continuous load that can be

delivered by the machine without exceeding the temperature rise for the insulation used, is termed as the continuous rating of the machine. Thus the load test alone can give us the proper information of the rating and also can help in the direct measurement of the efficiency.

9.5 Measurement of rotor inertia

The moment of inertia value is very important for the selection of a proper motor for drives involving many starts and stops or requiring very good speed control characteristics. The inertia can be determined by a retardation test.

The test works on the principle that when a motor is switched off from the mains it decelerates and comes to rest. The angular retardation at any speed is proportional to the retarding torque and is inversely proportional to the inertia. The torque lost at any speed is calculated by running the motor at that speed steadily on no load and noting the power input. From this power the losses that takes place in the armature and field are deducted to get the power converted into mechanical form. All this power is spent in overcoming the mechanical losses at that speed. This can be repeated at any defined speed to get the lost power (P_L) and torque lost (T_{lost}) due to mechanical losses. In a retardation test the motor speed is taken to some high value and the power to the motor is switched off. The torque required by the losses is supplied by the energy stored in the motor inertia. The lost torque at any speed can be written as

$$P_L = T_{lost} \cdot \omega \quad (53)$$

$$T_{lost} = P_L / \omega = J \frac{d\omega}{dt}$$

Here the $\frac{d\omega}{dt}$ is the slope of the retardation curve and the (T_{lost}) is the torque required to be

met at the given speed. From these values the moment of inertia can be computed as

$$J = \frac{T_{lost}}{\frac{dw}{dt}} = \frac{P_L}{w \cdot \frac{dw}{dt}} \text{kgm}^2 \quad (54)$$

9.6 Efficiency of a d.c. machine

A machine when loaded yields an output. The input to the machine is measured at that operating point. The efficiency in per unit is given as the ratio of output power to input power.

$$\begin{aligned} \eta &= \frac{\text{output power}}{\text{input power}} \\ &= \frac{\text{Input power} - \text{power lost inside the machine}}{\text{input power}} \\ &= \frac{\text{output power}}{\text{output power} + \text{power lost inside the machine}} \end{aligned} \quad (55)$$

The first definition is used in the direct estimation of the efficiency. The other two definitions are known as determination of efficiency using the loss segregation. For the segregation of losses one must know the losses that take place inside a d.c. machine. The losses that take place inside a d.c. machine can be listed as below.

1. Armature copper loss.
2. Brush and brush contact loss.
3. Shunt field loss
4. Series field loss
5. Commutating pole loss

6. Compensating winding loss
7. Mechanical losses
8. Iron losses
9. Stray load losses

Out of these items 1,2,7,8 and 9 will be present in all the d.c. machines. Out of the remaining one or more may be present depending on which winding is present. These losses change with temperature of operation. Mechanical losses vary with variation in speed. Iron losses change with the degree of saturation and distortion of the shape of the field flux distribution under the poles.

When a d.c. machine is loaded using a suitable load the output delivered by the machine increases. The input requirement also increases along with the output. The difference between the input and output powers is the power lost inside the machine as loss. The efficiency of power conversion is given by the ratio of output power to input power. Putting in mathematical form for a motor,

$$\eta = \frac{VI - \text{losses}}{VI} \quad (56)$$

for constant speed operation, the speed dependant losses remain constant. The load dependant losses form the variable losses. While the loss that takes place in the brush drop in the brushes is proportional to the load current, the loss that takes place in the resistance of the armature is proportional to the square of the load current. Even though the loss that takes place in a field winding is proportional to the square of the current through that winding, it is classified under constant losses as the excitation current is held constant during loading.

Thus the total losses in a d.c. motor can be expressed in the form

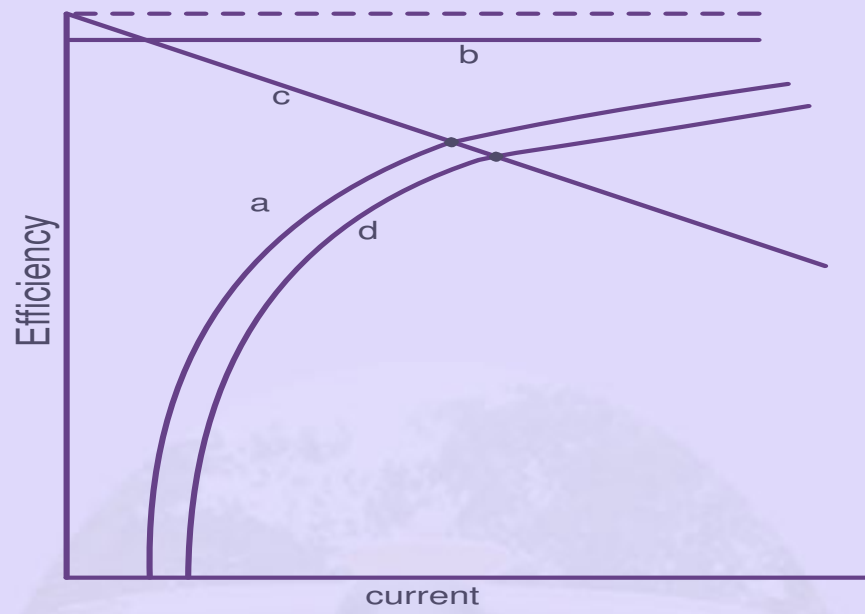
$$P_L = a + bI + cI^2 \quad (57)$$

$$\eta = \frac{VI - P_L}{VI} = 1 - \left(\frac{A}{I} + B + CI \right) \quad (58)$$

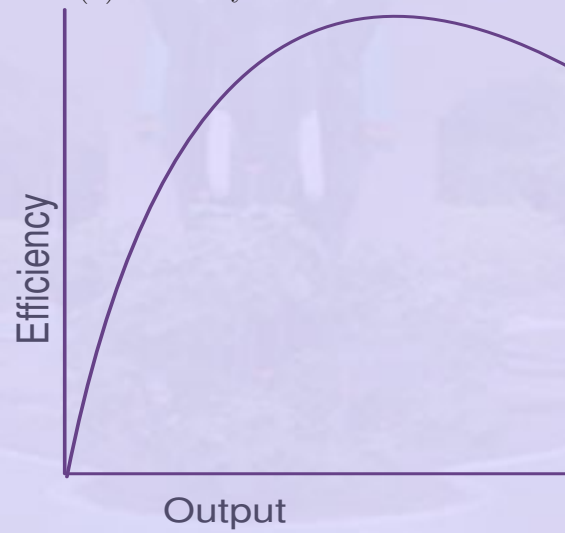
When $A = \frac{a}{V}$, $B = \frac{b}{V}$ and $C = cV$.

The term inside the brackets is sometimes referred to as the deficiency. For a typical d.c. motor these are plotted in Fig. 56(a) as a function of the load current. The curves a,b,c in the figure represent the efficiency curve taking one component of the loss at a time. The curve d is the efficiency curve with all three components taken together. The resultant curve exhibits a maximum. This can be easily seen from the graph that this maximum occurs when constant losses equal the variable losses. $\frac{A}{I} = CI$ or $A = CI^2$. Fig. 56(b) depicts a typical output vs η curve of a d.c. machine.





(a)Efficiency Vs Load current



(b)Output Vs Efficiency

Figure 56: Efficiency of a D.C.machine