5.5 Retardation Test or Running Down on D.C Machines

In this article, we are going to discuss retardation test on dc machines. Retardation test is also called as running down test. This is the very efficient way to find out stray losses in dc shunt motors. In this test, we get total stray losses nothing but the combination of mechanical (friction & windage) and iron losses of the machine.

The circuit diagram of retardation test on dc machines shown below. A1, A2 are armature terminals.

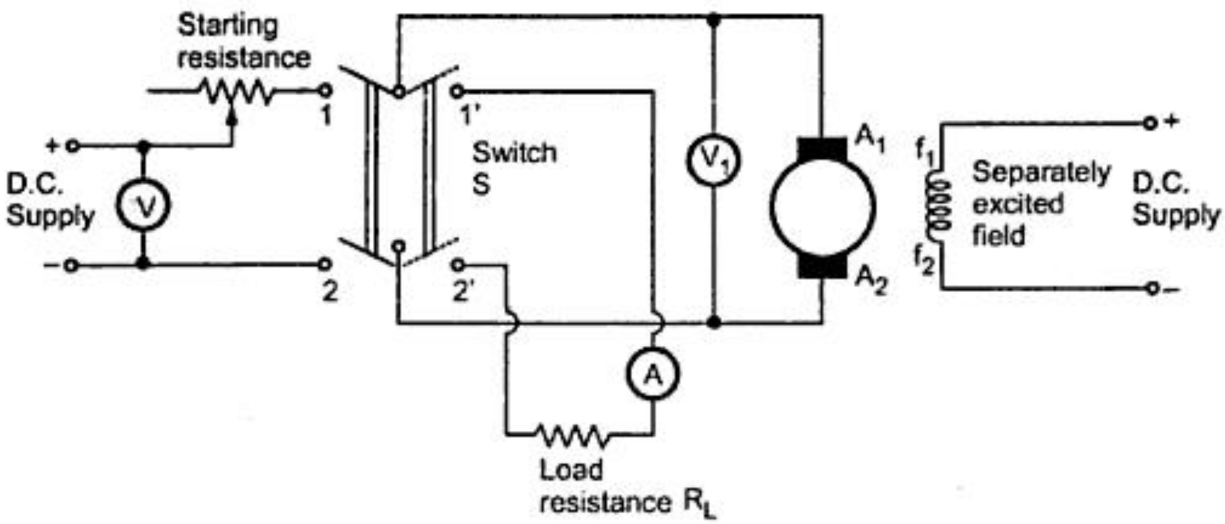

Figure 5.5.1 Retardation Test on D.C Machine

[Source: "'Electric Machinery Fundamentals" by Stephen J. Chapman, *Page: 402]*

The procedure of Retardation Test on D.C Machines

The main points in the retardation or running down test are discussed below,

1. Now start the dc machine normally, run the machine slightly above the rated speed by adjusting resistance.

2. After achieving the rated speed just cut off the power supply to the armature, but keeping field normally excited.

3. Now wait for some time to fall down of speed below rated, then using the tachometer note down the values of speed (in rpm) and time (in the sec).

4. The armature consequently slows down and the amount of kinetic energy present in the armature is used to supply the rotational or stray losses which include iron, friction and winding loss. If I am the amount of inertia of the armature and is the angular velocity.

The kinetic energy of armature = 0.5 $I\omega^2$.

Rotational losses, W = Rate of change of kinetic energy.

$$W = \frac{d}{dt}\left(\frac{1}{2}I\omega^2\right) = I\omega\frac{d\omega}{dt}$$

I=Moment of inertia of the armature.

In retardation test of dc machines, the rotational losses are given by

Let N = normal speed in r.p.m.

ω = normal angular velocity in rad/s = $2\pi N/60$

$\therefore$ Rotational losses, W = Rate of loss of K.E. of armature

or
$$W = \frac{d}{dt}\left(\frac{1}{2}I\omega^2\right) = I\omega\frac{d\omega}{dt}$$

Here I is the moment of inertia of the armature. As $\omega = 2\pi N/60$,

$$\therefore \quad W = I \times \frac{2\pi N}{60} \times \frac{d}{dt}\left(\frac{2\pi N}{60}\right) = \left(\frac{2\pi}{60}\right)^2 IN\frac{dN}{dt}$$

or
$$W = 0.011\, IN\frac{dN}{dt}$$

Swinburne's Test

For a d.c shunt motor change of speed from no load to full load is quite small. Therefore, mechanical loss can be assumed to remain same from no load to full load. Also if field current is held constant during loading, the core loss too can be assumed to remain same.

In this test, the motor is run at rated speed under *no load* condition at rated voltage. The current drawn from the supply *IL*0 and the field current *If* are recorded.

Since the motor is operating under no load condition, net mechanical output power is zero. Hence the gross power developed by the armature must supply the core loss and friction & windage losses of the motor. Therefore,

$$P_{core} + P_{friction} = \left(V - I_{a0} r_a\right) I_{a0} = E_{b0} I_{a0}$$

Since, both *Pcore* and *Pfriction* for a shunt motor remains practically constant from no load to full load, the sum of these losses is called constant rotational loss

$$\text{constant rotational loss, } P_{rot} = P_{core} + P_{friction}$$

In the Swinburne's test, the constant rotational loss comprising of core and friction loss is estimated from the above equation.

After knowing the value of *Prot* from the Swinburne's test, we can fairly estimate the efficiency of the motor at any loading condition. Let the motor be loaded such that new current drawn from the supply is *IL* and the new armature current is *Ia*

The biggest advantage of Swinburne's test is that the shunt machine is to be run as motor under *no load* condition requiring little power to be drawn from the supply; based on the no load reading, efficiency can be predicted for any load current. However, this test is not sufficient if we want to know more about its performance (effect of armature reaction, temperature rise, commutation etc.) when it is actually loaded. Obviously the solution is to load the machine by connecting mechanical load directly on the shaft for motor or by connecting loading rheostat across the terminals for generator operation. This although sounds simple but difficult to implement in the laboratory for high rating machines (say above 20 kW), Thus the laboratory must have proper supply to deliver such a large power corresponding to the rating of the machine. Secondly, one should have loads to absorb this power.

Calculation of efficiency

Let field currents of the machines be are so adjusted that the second machine is acting as generator with armature current *Iag* and the first machine is acting as motor with armature current *Iam* as shown in figure 40.7. Also let us assume the current drawn from the supply be *I*1. Total power drawn from supply is *VI*1 which goes to supply all the losses (namely Cu losses in armature & field and rotational losses) of both the machines

$$\begin{aligned}
\text{Power drawn from supply} &= VI_1 \\
\text{Field Cu loss for motor} &= VI_{fm} \\
\text{Field Cu loss for generator} &= VI_{fg} \\
\text{Armature Cu loss for motor} &= I_{am}^2 r_{am} \\
\text{Armature Cu loss for generator} &= I_{ag}^2 r_{ag} \\
\therefore \text{Rotational losses of both the machines} &= VI_1 - \left(VI_{fm} + VI_{fg} + I_{am}^2 r_{am} + I_{ag}^2 r_{ag}\right)
\end{aligned}$$

Since speed of both the machines are same, it is reasonable to assume the rotational losses of both the machines are equal; which is strictly not correct as the field current of the generator will be a bit more than the field current of the motor, Thus, Once *Prot* is estimated for each machine we can proceed to calculate the efficiency of the machines as follows,

$$\text{Rotational loss of each machine, } P_{rot} = \frac{VI_1 - \left(VI_{fm} + VI_{fg} + I_{am}^2 r_{am} + I_{ag}^2 r_{ag}\right)}{2}$$

Efficiency of the motor

As pointed out earlier, for efficiency calculation of motor, first calculate the input power and then subtract the losses to get the output mechanical power as shown below,

$$\begin{aligned}
\text{Total power input to the motor} &= \text{power input to its field} + \text{power input to its armature} \\
P_{inm} &= VI_{fm} + VI_{am} \\
\text{Losses of the motor} &= VI_{fm} + I_{am}^2 r_{am} + P_{rot} \\
\text{Net mechanical output power } P_{outm} &= P_{inm} - \left(VI_{fm} + I_{am}^2 r_{am} + P_{rot}\right) \\
\therefore \eta_m &= \frac{P_{outm}}{P_{inm}}
\end{aligned}$$

Efficiency Of Generator

$$\text{Losses of the generator} = VI_{fg} + I_{ag}^2 r_{ag} + P_{rot}$$

$$\text{Input power to the generator, } P_{ing} = P_{outg} + \left(VI_{fg} + I_{ag}^2 r_{ag} + P_{rot}\right)$$

$$\therefore \eta_g = \frac{P_{outg}}{P_{ing}}$$

Hopkinson's Test

This as an elegant method of testing d.c machines. Here it will be shown that while power drawn from the supply only corresponds to no load losses of the machines, the armature physically carries any amount of current (which can be controlled with ease). Such a scenario can be created using two similar mechanically coupled shunt machines. Electrically these two machines are eventually connected in parallel and controlled in such a way that one machine acts as a generator and the other as motor. In other words two similar machines are required to carry out this testing which is not a bad proposition for manufacturer as large numbers of similar machines are manufactured.

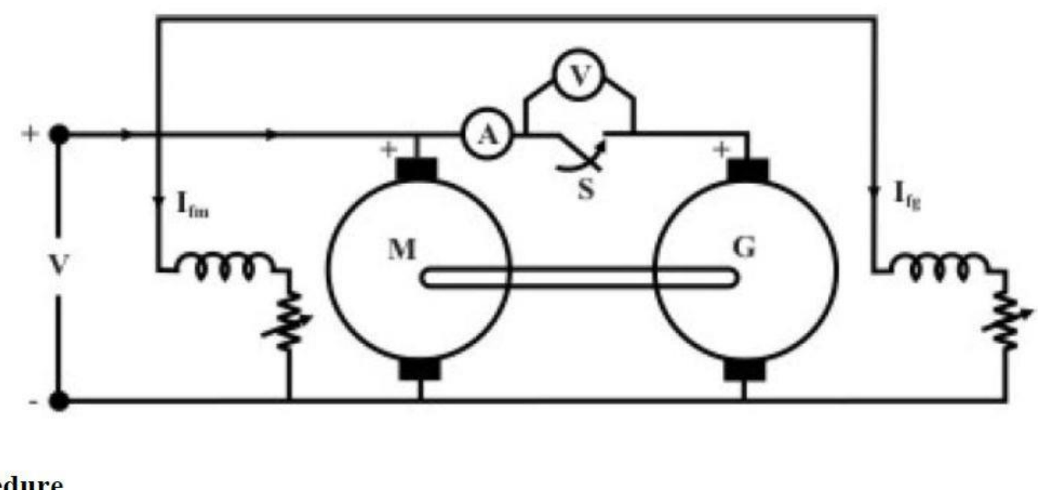

Figure 5.5.2 Hopkinson Test

[Source: "Electric Machinery Fundamentals" by Stephen J. Chapman*, Page: 411]*

Procedure

Connect the two similar (same rating) coupled machines as shown in figure 40.6. With switch S opened, the first machine is run as a shunt motor at rated speed. It may be noted that the second machine is operating as a separately excited generator because its field winding is excited and it is driven by the first machine. Now the question is what will be the reading of the voltmeter connected across the opened switch S? The reading may be (i) either close to twice supply voltage or (ii) small voltage. In fact the voltmeter practically reads the difference of the induced voltages in the armature of the machines. The upper armature terminal of the generator may have either + ve or negative polarity. If it happens to be +ve, then voltmeter reading will be small otherwise it will be almost double the supply voltage

Since the goal is to connect the two machines in parallel, we must first ensure voltmeter reading is small. In case we find voltmeter reading is high, we should switch off the supply, reverse the armature connection of the generator and start afresh. Now voltmeter is found to read small although time is still not ripe enough to close S for paralleling the machines. Any attempt to close the switch may result into large circulating current as the armature resistances are small. Now by adjusting the field current I_{fg} of the generator the voltmeter reading may be adjusted to zero ($E_g \approx E_b$) and S is now closed. Both the machines are now connected in parallel

Loading the machines

After the machines are successfully connected in parallel, we go for loading the machines i.e., increasing the armature currents. Just after paralleling the ammeter reading A will be close to zero as $E_g \approx E_b$. Now if I_{fg} is increased (by decreasing R_{fg}), then E_g becomes greater than E_b and both I_{ag} and I_{am} increase, Thus by increasing field current of generator (alternatively decreasing field current of motor) one can make $E_g > E_b$ so as to make the second machine act as generator and first machine as motor. In practice, it is also required to control the field current of the motor I_{fm} to maintain speed constant at rated value. The interesting point to be noted here is that *Iag* and *Iam* do not reflect in the supply side line. Thus current drawn from supply remains small (corresponding to losses of both the machines). The loading is sustained by the output power of the generator running

Advantages of Hopkinson's Test

1. This test requires very small power compared to full- load power of the motor-generator coupled system. That is why it is economical.

2. Temperature rise and commutation can be observed and maintained in the limit because this test is done under full load condition.

3. Change in iron loss due to flux distortion can be taken into account due to the advantage of its full load condition

Disadvantages of Hopkinson's Test

The demerits of this test are

1. It is difficult to find two identical machines needed for Hopkinson's test.

2. Both machines cannot be loaded equally all the time.

3. It is not possible to get separate iron losses for the two machines though they are different because of their excitations.

4. It is difficult to operate the machines at rated speed because field currents vary widely.

39.8 Braking of d.c shunt motor: basic idea

It is often necessary in many applications to stop a running motor rather quickly. We know that any moving or rotating object acquires kinetic energy. Therefore, how fast we can bring the object to rest will depend essentially upon how quickly we can extract its kinetic energy and make arrangement to dissipate that energy somewhere else. If you stop pedaling your bicycle, it will eventually come to a stop eventually after moving quite some distance. The initial kinetic energy stored, in this case dissipates as heat in the friction of the road. However, to make the stopping faster, brake is applied with the help of rubber brake shoes on the rim of the wheels. Thus stored K.E now gets two ways of getting dissipated, one at the wheel-brake shoe interface (where most of the energy is dissipated) and the other at the road-tier interface. This is a good method no doubt, but regular maintenance of brake shoes due to wear and tear is necessary.

If a motor is simply disconnected from supply it will eventually come to stop no doubt, but will take longer time particularly for large motors having high rotational inertia. Because here the stored energy has to dissipate mainly through bearing friction and wind friction. The situation can be improved, by forcing the motor to operate as a generator during braking. The idea can be understood remembering that in motor mode electromagnetic torque acts along the direction of rotation while in generator the electromagnetic torque acts in the opposite direction of rotation. Thus by forcing the machine to operate as generator during the braking period, a torque opposite to the direction of rotation will be imposed on the shaft, thereby helping the machine to come to stop quickly. During braking action, the initial K.E stored in the rotor is either dissipated in an external resistance or fed back to the supply or both