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Speed control of a DC series motor

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ABSTRACT

This paper presents the speed control of DC series motor by using field control method, armature control method and voltage control method. In field control method, a variable resistance is connected in parallel with series field winding to shunt some portion of the line current from the series field winding. Thus weakening the field and increasing the speed. While in armature control method, a variable resistance is directly connected in series with the supply to reduce the voltage available across the armature and hence the speed falls. For voltage control method, the motor is supplying with a variable voltage supply to change the speed of the motor. A laboratory experiment is designed to control the speed of dc series motor where a rheostat (variable resistor) is used to vary the field and armature resistance of the motor. The applied voltage is kept constant for both field control method and armature control method experiment. The result of the experiment shows at a constant supplied voltage, the speed of the motor increased when the flux and armature resistance decreased. Meanwhile, the speed of the motor increased when the terminal voltage increased. This study concluded that the speed of a series DC motor can be controlled by varying the field, armature and supplied voltage.

1. Introduction

DC motors are seldom used in ordinary applications because all electric supply companies furnish alternating current. However, for special applications such as in steel mills, mines and electric trains, it is advantageous to convert alternating current into direct current in order to use DC motors. The reason is that speed or torque characteristics of DC motors are much more superior compared to that AC motors. Therefore, it is not surprising to note that for industrial drives, DC motors are as popular as three-phase induction motors.

A machine that converts DC power into mechanical power is known as DC motor. Its operation is based on the principle that when a current carrying conductor is placed in a magnetic field, its

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experiences a torque and has tendency to move [1] .This is known as motoring action. If the direction of current in the wire is reversed, the direction of rotation also reverses. When magnetic field and electric field interact, they produce a mechanical force and based on that the working principle of DC motor is established.

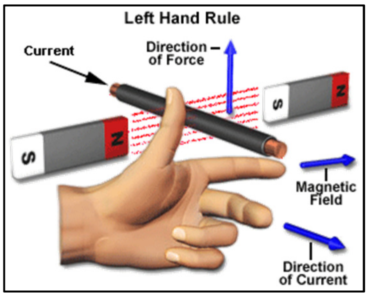

Fig. 1. Fleming's Left Hand Rule

Figure 1 shows the direction of rotation of DC motor given by Fleming's left hand rule. The index finger, middle finger and thumb of left hand are extended mutual perpendicular to each other. The index finger represents the direction of magnetic field, middle finger indicates the direction of current and then the thumb represents the direction in which force is experienced by the shaft of the DC motor [2].

In a DC motor, the supply voltage, E and current, I is given to the electrical port or input port and we derive the mechanical output i.e. torque, T and speed, ω from the mechanical port or output port. The input and output port variables of the direct current motor are related by the parameter K [3].

$$T = KI \quad \text{and} \quad E = K\omega \tag{1}$$

Figure 2 shows the schematic diagram of a series DC motor. The field winding is connected in series with the armature. Therefore, series field winding carries the armature current. Since the current passing through a series field winding is the same as the armature current, series field windings must be designed with much fewer turns than shunt field windings for the same m.m.f. Therefore, a series field winding has a relatively small number of turns of thick wire and therefore, will possess a low resistance. If the mechanical load on the motor increases, the armature current also increases. Hence, the flux in a series motor increases with the increase in armature current and vice-versa [1].

The aim of this study is to show that the speed of a DC series motor can be controlled by varying the field, armature resistance and terminal voltage experimentally.

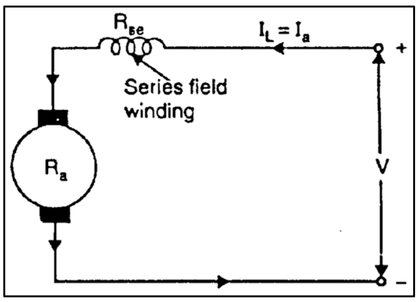

Fig. 2. Series DC Motor

2. Literature Review

Speed control means intentional change of the drive speed to a value required for performing the specific work process. The principal advantage of a DC motor is that its speed can be changed over a wide range by a variety of simple methods. Speed control is either done manually by the operator or by means of some automatic control device. The speed of a dc motor is given by,

$$N \propto \frac{E_b}{\phi}$$

or

$$N = k\frac{(V - I_a R)}{\phi}\ r.p.m. \tag{2}$$

where $R = R_a$ (for shunt motor)
$R = R_a + R_{se}$ (for series motor)

From Eq. (2), it is clear that there are three mains methods to control the speed of a DC motor which are,

i) Armature control method by varying the resistance in the armature circuit (R_a).
ii) Voltage control method by varying the applied voltage (V).
iii) Field control method by varying the flux per pole (ϕ).

The first two methods involve change that affects the armature circuit and the third one involves change in magnetic field. Therefore, speed control of DC motor is classified as:

i) Armature control methods
ii) Field control methods

3. Speed control of dc series motor

Speed control of a DC series motor can be done either by armature control or by field control.

3.1. Armature control of DC series motor

Speed adjustment of DC series motor by armature control may be done by any one of the methods.

3.1.1. Armature resistance control method

In this method, a variable resistor is directly connected in series with the supply to complete the motor as shown in Fig. 3 [1]. This reduces the voltage available across the armature and hence the speed falls. This is the most common method employed to control the speed of DC series motors. The loss of power in the series resistance for many applications of series motors is not too serious. The control is to reduce the speed under light-load conditions and is only used intermittently when the motor is carrying full-load.

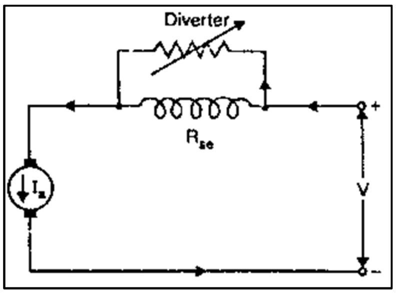

Fig. 3. Field diverter method

3.1.2. Armature terminal voltage control

The speed control of DC series motor can be accomplished by supplying the power to the motor from a separate variable voltage supply [4]. This method involves high cost so it rarely used.

3.2. Field control of DC series motor

In this method, the flux produced by the series motor is varied and hence the speed. The variation of flux can be achieved in the following ways:

3.2.1. Field diverter method

This method uses a variable resistor called diverter. It is connected in parallel with the series field winding as shown in Fig. 4 [1]. Here the field flux can be reduced by shunting a portion of motor current around the series field. Lesser the diverter resistance, less is the field current, less flux therefore more speed [4]. It is used in electric drives in which speed should rise sharply as soon as load is decreased such as traction work.

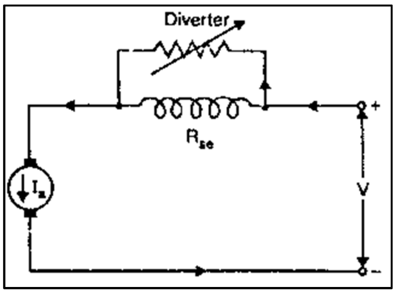

Fig. 4. Field diverter method

3.2.2. Armature diverter method

In order to obtain speeds below the normal speed, a variable resistance called armature diverter is connected in parallel with the armature as shown in Fig. 5 [1]. The diverter shunts of the line current, thus reducing the armature current. So for a given load, if I_a is decreased, the flux, ϕ must increase. Since the speed is inversely proportional to the flux, therefore the speed is decreased.

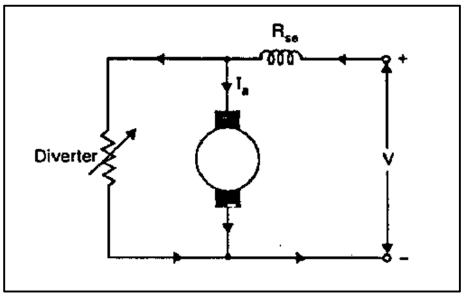

Fig. 5. Armature diverter method

3.2.3. Tapped field control

In this method, the flux is reduced and hence the speed is increased by decreasing the number of turns of the series field winding as shown in Fig. 6 [1]. The switch, S can short circuit any part of the field winding, thus decreasing the flux and raising the speed. With full turns of the field winding, the motor runs at normal speed and as the field turns are cut out, speeds higher than normal speed are achieved.

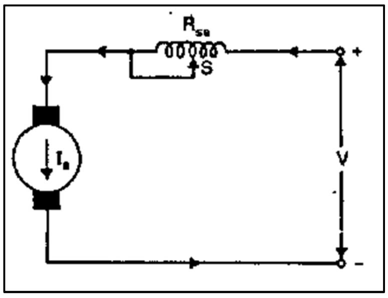

Fig. 6. Tapped field control

3.2.4. Paralleling field coils

This method is usually used in the case of fan motors. By regrouping the field coils as shown in Fig. 7 [1], several fixed speed can be achieved.

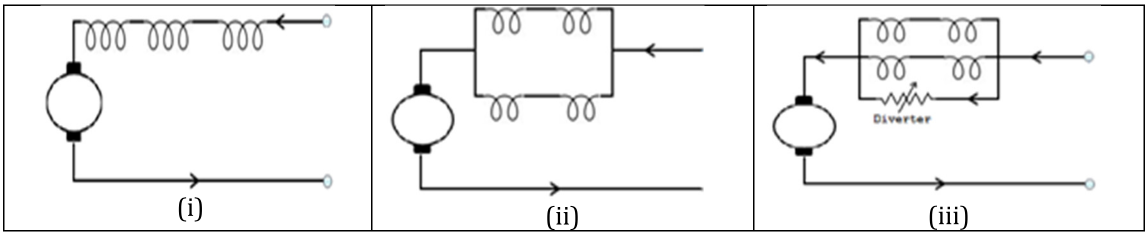

Fig. 7. Paralleling field coils

4. Method of Study

4.1. Equipments

Speed control of a DC series motor experiments include a series DC motor DL1023S or compound DC motor DL1023, multi meters, tachometer and rheostat. Fig. 8 shows the main experimental instruments.

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(a) De Lorenzo DC Motor Series Excitation

(b) De Lorenzo Starting Rheostat

(c) Multimeter

(d) Tachometer

Fig. 8. Experimental instruments

4.2. Experimental Setup

Figure 9 shows the experimental setup of field resistance control method. A rheostat acts as an external resistance is connected in parallel with the series field winding of a DC series motor to control the motor speed. The value of external resistances are varied by changing the rheostat knob at a constant terminal voltage.

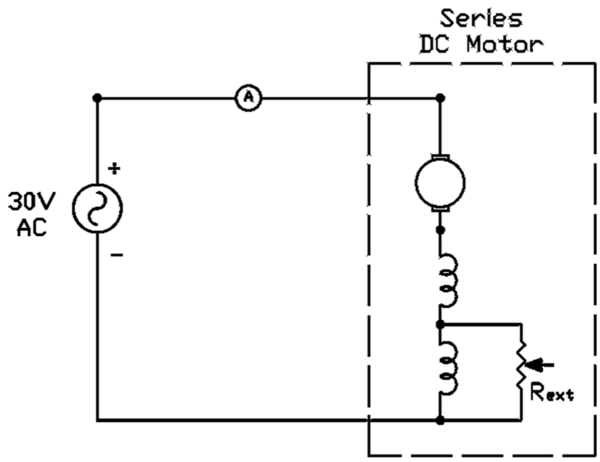

Fig. 9. Experimental setup of field resistance control method

The field flux is reduced due to the effects of adding an external resistance in parallel with the series field winding of series DC motor. The increasing of external resistances reduce the line current around the field winding as shown in Fig. 10. The external resistances are inversely proportional to the field current. If the external resistance increased, the field current will decreased and hence the flux will also decreased. Since speed is directly proportional to the flux, the speed of the DC series motor increased when the flux decreased as shown in Fig. 11.

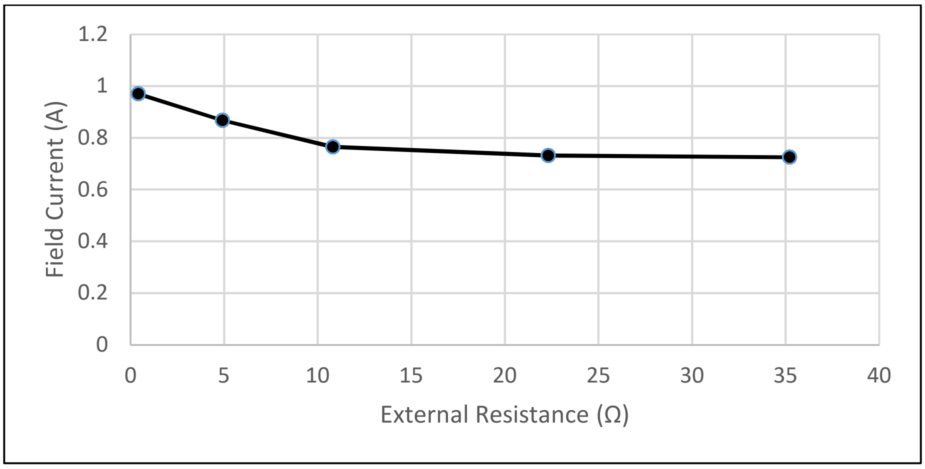

Fig. 10. Effects of external resistance addition towards the motor's field current

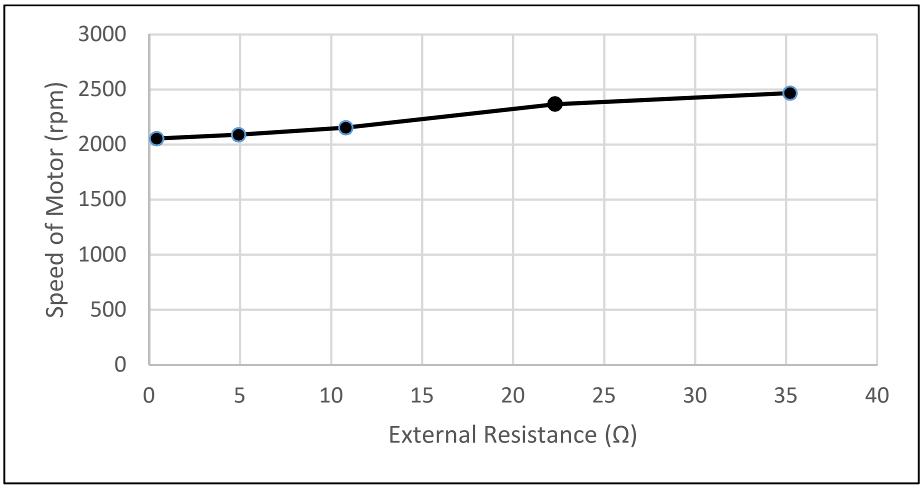

Fig. 11. Effects of external resistance addition towards the speed of series DC motor

Fig. 12 shows the experimental setup of armature resistance control method. A rheostat is directly connected in series with the power supply to the DC series motor. The value of external resistances are varied by changing the rheostat knob at a constant terminal voltage. The voltage across the armature decreased when the external resistance in series with the armature increased. As a result, the speed of the DC series motor will decreased.

The equipment are connected as shown in Fig. 14 where the connection is excluding from the external resistance for terminal voltage control method. The experiment are only used the DC series motor itself connected with separate variable voltage supply. The speed of the motor increased as the voltage supply increased.

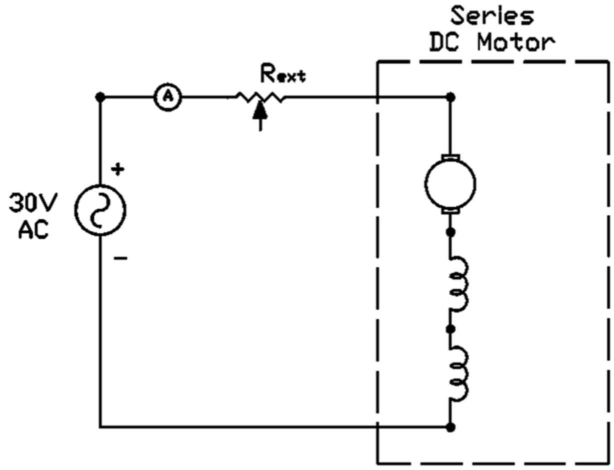

Fig. 12. Experimental setup of armature resistance control method

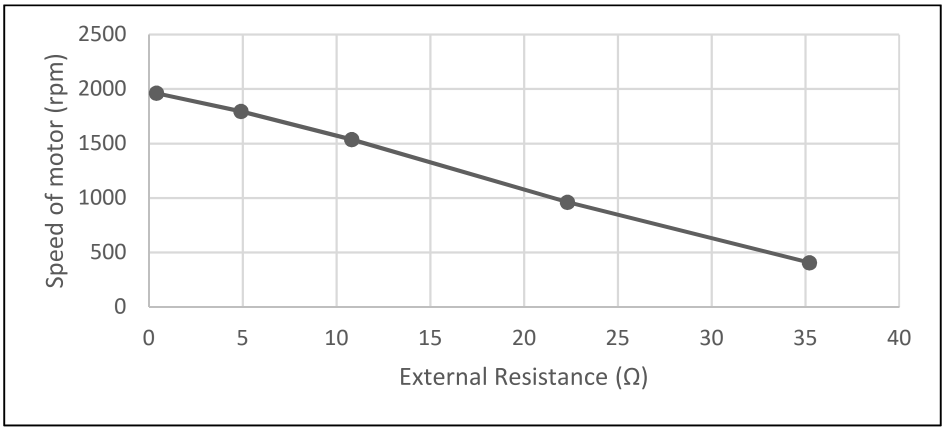

Fig. 13. Effects of external resistance in series with the motor towards the motor's speed

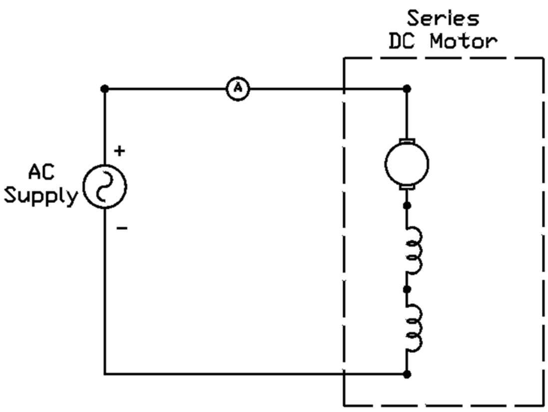

Fig. 14. Experimental setup of terminal voltage control method

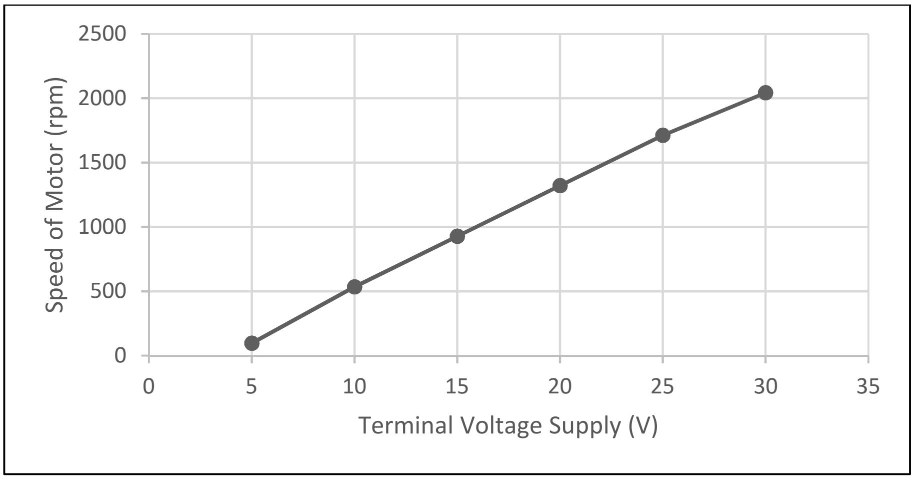

Fig. 15. Effects of the separate variable voltage supply towards the motor's speed

5. Conclusion

Based on experiments conducted, this study found that by varying the field, armature resistance and terminal voltage, the speed of DC series motor can be controlled. The armature resistance control method is the most common method employed to control the speed of DC series motor. The voltage control method is rarely used because it involves high cost.

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