NUEVA GRANADA MILITARY UNIVERSITY

LABORATORY: DC MOTOR SERIAL CONNECTION

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1. RESUMEN:

Durante la práctica de laboratorio se realizará la conexión de un motor de corriente continua en serie y de esta manera determinar las características que posee.

Se procede a realizar diversas mediciones de velocidad, voltaje y corriente para tener un mejor acercamiento al motor.

2. PALABRAS CLAVE

- Devanado
- Potencia
- Carga
- Torque
- Campo magnético
-

3. ABSTRACT:

During the practice of laboratory is will take to out the connection of a motor of current continuous in series and of this way determine the features that has.

It's proceeded to perform various measurements of speed, voltage and current to have a better approach to the engine.

4. KEY WORDS

- Winding
- Power
- Load
- Torque
- Magnetic field

5. INTRODUCTION:

Electric direct current motors are devices capable of transforming electrical energy into mechanical energy, in this case a rotational movement. Its operation is based on the force produced by the presence of a conductive material, such as in the form of a coil, excited with a current intensity within a magnetic field present by a magnet or electromagnet.

When motors have their magnetic field produced by an electromagnet, they have an additional winding inside responsible for behaving like an electromagnet. The motor can have the windings and the power supply connected in series.

6. OBJECTIVES

GENERAL OBJECTIVE:

- Analyze the characteristics of a motor with winding and power connected in series.

SPECIFIC OBJECTIVES:

- Analyze the behavior of voltages in the windings at different loads.
- Determine and analyze the torque value, using the ratio of speed and supply voltage.

7. THEORETICAL FRAMEWORK:

➢ ELECTRODYNAMOMETER:

The electrodynamometer is an instrument in which the torque produced comes from the magnetic forces between coils that conduct currents, one of which is rotating.

This device was implemented during the practice to place a load on the motor and in this way determine various ratios of currents and voltages according to the load that was placed on the motor.

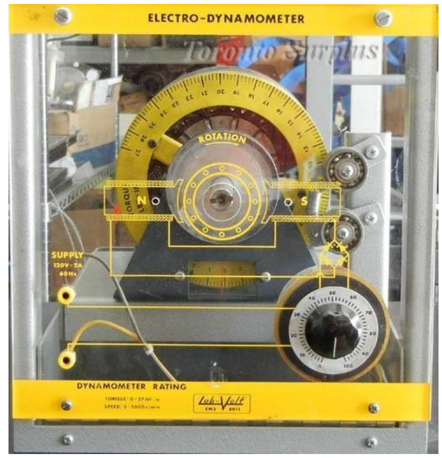


Figure 1. Lab-volt electrodynamometer[1]

➢ DIRECT CURRENT MOTOR:

It is a machine that converts electrical energy into mechanical energy, through a rotating movement, by means of the magnetic field.

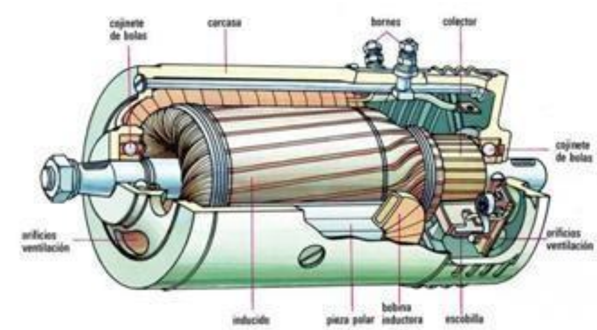


Figure 2. Direct current motor [2]

Figure 3. Lab-volt DIRECT current motor [3]

- **SERIAL CONNECTION:**

"A series motor is a type of direct current electric motor in which the field winding (main magnetic field) is connected in series with the armature. This winding is made by a thick wire, already will have to withstand the full current of the armor. Due to this a magnetic flux occurs proportional to the armature current (motor load)." [1]

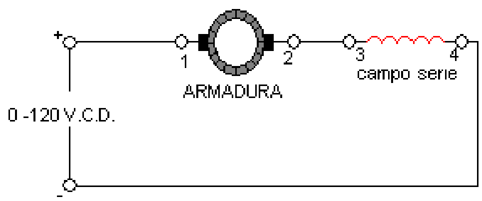


Figure 4. Direct current motor [4]

8. METHODOLOGY:

During the practice the design for a motor with the windings connected in series will be carried out. The internal structure of a motor with serial windings is as follows:

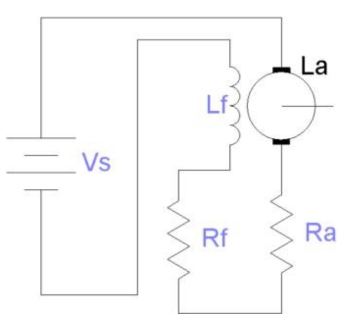


Figure 5. Internal structure.

Formulas:

$$Ia = If \qquad Ec\ 1.$$

$$Ea = Vs - RI \qquad Ec\ 2.$$

$$Ka\emptyset p = \frac{Ea}{Wm} \qquad Ec\ 3.$$

$$Td = Ka\emptyset p\,.\,Ia^2 \qquad Ec\ 4.$$

$$Pd = EaI \qquad Ec\ 5.$$

Where:

R: Equivalent resistance (Ra + Rf)

Vs: Source voltage

I: Current

Ea: Counter-electromotive voltage

Ia: Armature current (Ia = If)

Pd: Power developed

Td: Torque developed

Wm: Angular velocity

As the objectives seek to find the torque developed, the following equations are implemented from equation 5:

$$Pd = EaI$$

$$Pd = TdWm \qquad Ec\ 6.$$

$$EaIa = \ TdWm \qquad Ec\ 7.$$

Therefore, when making the current and speed measurements, the torque value can be found, from equations 6 and 7:

$$Td = \frac{EaIa}{Wm}$$

$$o$$

$$Td = \frac{Pd}{Wm}$$

To carry out the practice, the following materials are used::

- Alligator clips
- Three-phase cable
- Tachometer
- Power table
- Multimeter
- Banana-banana connection cables
- Universal DC motor
- Electrodynamometer
- Distribution strap
- Voltage source

- **Procedure:**

1. The parts of the motor, the electro-dynamometer and the power supply are identified to have a proper connection.
2. Perform measurements for supply voltage.
3. Take the measurements of voltage, speed and current when the motor is without load and subsequently with different loads.
4. By means of the values taken and taking into account the equations mentioned above, the torque developed experimentally is found.
5. When performing the respective calculations, we proceed to relate the speed as a function of torque and to be able to obtain its graph in order to analyze its behavior.
6. Another graphed result of torque as a function of current is obtained to verify its exponential behavior.
7. The graphics previous obtained both theoretically and experimentally are compared to find their respective relationships.

Through the simulation you can have a greater approach to the results that will be found during the practice and perform the respective relationships, as can be seen below:

- Test, simulation and analysis plan

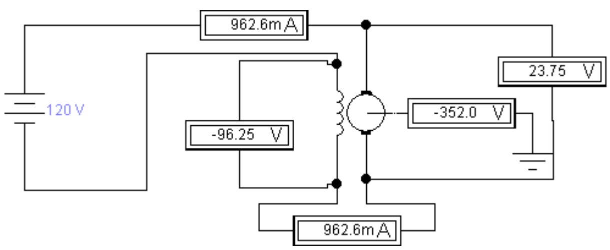


Figure 6. DC motor simulation

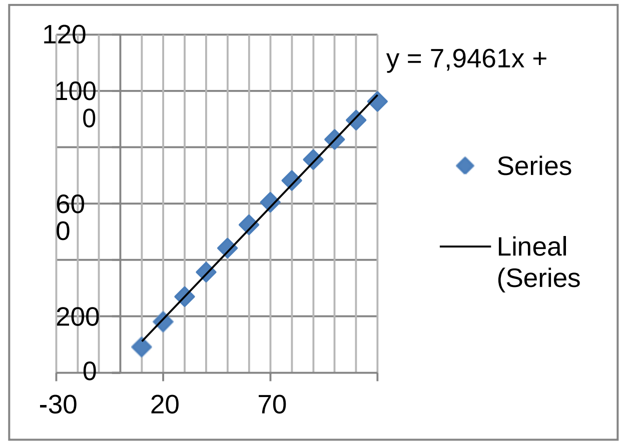
- Test plan:

Different simulations are carried out varying their voltage to be able to analyze their performing behaviour. A DC motor with the following characteristics is simulated: Armature resistance 10 ohms, armature inductance, 1mH, field resistance 100 ohms and field inductance equal to 1mH.

Voltage (v)	Current (mA)
10	90.81
20	181.0
30	269.9
40	357.1
50	442.1
60	524.7
70	604.6
80	681.7
90	756.1
100	827.6
110	896.4
120	962.6

Table 1. Current values in voltage variation

By performing the simulations with 10 different voltage data it can be evidenced that as its voltage increases the current becomes larger, being directly proportional.



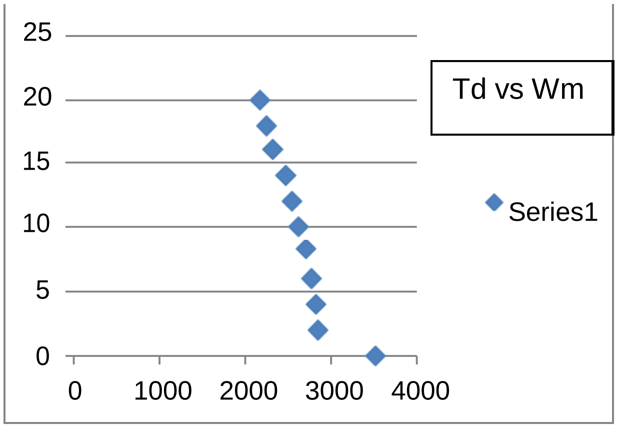
Graph 1. Current as a function of voltage

When relating Torque to Angular Velocity, the following was obtained:

Speed(rpm)	Torque (Nm)
3520	0
2849	2
2825	4
2774	6
2699	8
2623	10
2548	12
2473	14
2322	16
2247	18
2171	20

Tabla 2. Torque values in NM and speed in rpm

It is observed that as the Torque rises in value, the angular velocity of the motor begins to decrease in its value, and this is where the increase in power occurs.



Graph 2. Torque developed vs Motor angular velocity

Taking into account by Ohm's law that the behavior of the current is inversely proportional to the value of the resistance where a voltage, generating a current. Then you have to for the circuit in series, then complying with Kirchoff's laws for meshes, the current is one in the whole circuit, it is the same that passes through the resistors and inductors that make up the motor.

As the load on the system increased, the speed decreased but the power exerted by the engine was the variable that increased. Because power and torque are directly proportional variables.

8. EXPERIMENTAL RESULTS

During the practice, various velocity and current measurements were made, using variations in load and voltage, to determine the reactions of the system through the changes as can be seen in the following table:

Voltage (V)	*Speed (rpm)*	*Current (A)*	*Load (Nm)*
50	*735*	*900mA*	*Machine*
119	*1550*	*2,94A*	*0.12*
50	*1491*	*1,26A*	*0.15*
68	*1810*	*1,21A*	*0.15*
68	*1530*	*1,46A*	*0.23*
76	*1790*	*1,39A*	*0.23*
76	*1600*	*1,55A*	*0.33*
81	*1826*	*1.47A*	*0.28*
81	*1532*	*1,76A*	*0.45*
87	*1795*	*1,64A*	*0.41*
87	*1500*	*2,01A*	*0.56*
98	*1792*	*1,85A*	*0.52*
98	*1640*	*2,04A*	*0.68*
102	*1807*	*1,94A*	*0.59*
102	*1570*	*2,29A*	*0.79*
110	*1795*	*2,14A*	*0.72*
110	*1625*	*2,39A*	*0.9*
114	*1801*	*2,27A*	*0.81*
114	*1600*	*2,62A*	*1.02*
119	*1800*	*2,4A*	*0.93*
119	*1680*	*2,64A*	*1.02*
119	*1650*	*2,74A*	*1.13*

Table 3. Experimental values serial connectionserie

The charge involved in Table 3 is the one implemented with the electrodynamometer, this device has the scale of the charges in lbf*in which were changed by Nm by the following conversion.

9. ANALYSIS OF RESULTS:

The motor has different characteristics depending on how it is connected, in this case a serial connection was used. The motor was fed with different voltages which were varied in a range of 50V to 120V which is its nominal voltage, as these voltages were varied it was placed load, because these motors do not have a constant speed, if they start without load they tend to take a lot of speed and can become harmful to the motor.

By means of the data obtained, the following calculations can be made, finding the characteristics of the implemented engine.

Using equation 6 to find power.

$$Pd = 1.13Nm * 169.64\ rad/s$$

$$Pd = 191.69W$$

Equation 7 to find voltage in the armature.

$$Ea = \frac{TdWm}{Ia}$$

$$Ea = \frac{1.13Nm * 169.64rad/s}{2.74A}$$

$$Ea = 69.96V$$

As a motor with serial connection, the following relationship is fulfilled:

$$Ia = If$$

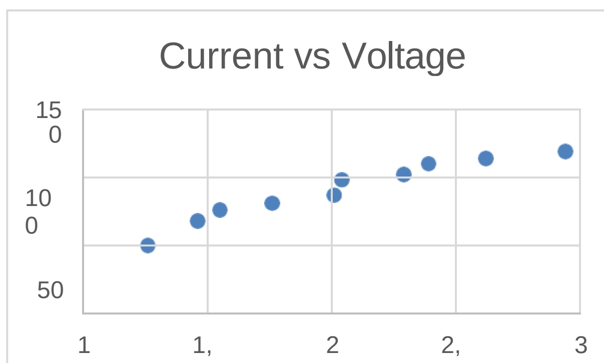
As the developed power is already found, by means of the experimental data, the value of the torque can be found:

$$Td = \frac{Pd}{Wm}$$

$$Td = \frac{191.64W}{169.64rad/s}$$

$$Td = 1.1296Nm$$

By means of the data obtained, the following graph is presented:



Graph 3. Current Vs motor voltage, with experimental data

Where it is possible to show that as the voltage increases, the current and speed of the motor increase being directly proportional, but as the load increases the motor loses speed, but its torque increases.

10. CONCLUSIONS:

- In this type of connection the motor has a start where there is a high peak in current that can damage the motor and its speed is not constant.
- The speed of the motor is inversely proportional to the torque, the more torque required by the motor, the speed decreased.
- When the motor has no load, its current is nominal, the current increases when it needs to apply a higher torque, it means that the speed is not proportional to the current when there is a load.
- The current is directly proportional to the voltage, whether or not the motor is loaded.
- The motor having this type of connection (in series), the speed is difficult to control, this connection is not used for a speed control.

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