American University of Beirut

Faculty of Engineering and Architecture

Department of Electrical and Computer Engineering

Electric Machines Lab\_EECE 470L

Experiment 4

Load Test on a DC Series Motor

Objectives:

The objectives of this experiment are to determine the load and control characteristics of a dc series motor supplied at constant voltage and to study the motor efficiency when operating at a constant load. This lab introduces the basic concepts of DC motors, mostly used for high starting torque applications

Procedure:



 Figure 1: DC series motor connected to the automatic starter

The circuit was connected as shown in Figure1. In the first part the 1 Ohm resistor is set to zero value. The DC supply voltage of the motor is maintained constant at 110 volts. The load test start at 20% overload and then decreased with us taking values of the motor current, speed and brake angle. The 16 ohms variable resistor is used to maintain the voltage at 110 Volts. This part is repeated but with the 1 ohm resistor set to the maximum values. Measurements of the motor current, speed and brake angle are also taken. In the third part, the value of the 1 ohm resistor is set to zero again. This time the brake angle was maintained constant to 20 degrees, and the motor voltage was varied from 110 Volts to 50 Volts. Measurements of the motor current, speed and brake angle are also taken. The last part consists of the calibration of the prony brake by putting masses (mechanical torque) and taking measurements of the Brake angle to determine the load.

Apparatus:

1. DC series Motor

2. Variable 1 ohm resistor

3. Variable 16 ohms resistor

4. 20 A Ammeter

5. 150 Volts Voltmeter

6. Taco-Meter

7. 110 Volts DC supply

Measured Data Tabulation:

Note: at no load, the no load voltage is 110 V, and the speed of the dc series motor is 1500 RPM.

The value of the 1 ohm resistor is zero.

|  |  |  |
| --- | --- | --- |
| Current (A) | Speed (RPM) | Angle (Degrees) |
| 2.1 | 1200 | 7 |
| 5 | 825 | 13 |
| 6.8 | 700 | 22 |
| 9 | 600 | 29 |
| 12 | 500 | 40 |
| 14.2 | 450 | 48 |

The value of the 1 ohm resistor is maximum.

|  |  |  |
| --- | --- | --- |
| Current (A) | Speed (RPM) | Angle (Degrees) |
| 2.6 | 1000 | 10 |
| 5.2 | 700 | 16 |
| 9.3 | 550 | 30 |
| 12 | 450 | 41 |
| 15 | 350 | 48 |

Constant Torque and variable voltage.

At constant torque angle of 25 degrees, the constant current is 7.2 A.

|  |  |  |
| --- | --- | --- |
| Voltage (Volts) | Current (A) | Speed (RPM) |
| 100 | 7.2 | 600 |
| 90 | 7.2 | 530 |
| 80 | 7.2 | 450 |
| 70 | 7.2 | 400 |
| 60 | 7.2 | 300 |
| 50 | 7.2 | 250 |

Calibration of the prony Brake

|  |  |
| --- | --- |
| Mass (Kg) | Angle (Degrees) |
| 0.25 | 6 |
| 1 | 8 |
| 2 | 11 |
| 4 | 19 |
| 6 | 26 |
| 8 | 34 |
| 9 | 37 |

Questions, Graphs and Comments:

I- the torque- Brake angle calibration curve.

To get the plot we will consider the data in table 4, (Mass and Angle). We have the following formulas:

$$Torque=mgR \cos(\left(θ-θ\_{h}\right), with )θ\_{h}=25 degrees, R=0.204 m and g=10$$

We can obtain with the above formula the following table:

|  |  |  |
| --- | --- | --- |
| Mass (Kg) | Angle (degrees) | Torque |
| 0.25 | 6 | 0.47 |
| 1 | 8 | 1.95 |
| 2 | 11 | 3.96 |
| 4 | 19 | 8.12 |
| 6 | 26 | 12.24 |
| 8 | 34 | 16.12 |
| 9 | 37 | 17.96 |

Comment: As expected, the characteristic is a straight line and the torque is proportional to the prony angle.

II-Calculation and graph of the torque, speed, horsepower output, and efficiency to a base of motor current for the test in procedure part I.

The torque induced is equal to $\frac{110\*current}{w \left(\frac{rad}{s}\right)}$

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Current | Speed | Angle  | $$τ\_{load}$$ | $$P\_{out}$$ | Efficiency | $$τ\_{induced}$$ | $$P\_{in }$$ |
| 2.1 | 1200 | 7 | 0.5 | 63 | 28% | 1.84 | 231 |
| 5 | 825 | 13 | 4 | 346 | 63 | 7 | 550 |
| 6.8 | 700 | 22 | 8.5 | 623 | 84% | 10.2 | 748 |
| 9 | 600 | 29 | 14 | 880 | 89% | 16 | 990 |
| 12 | 500 | 40 | 20 | 1047 | 79% | 26 | 1320 |
| 14.2 | 450 | 48 | 27 | 1273 | 82% | 30 | 1562 |

The torque load can be obtained from the graph of part I.

III-Calculation and graph of the torque, speed, horsepower output, and efficiency to a base of motor current for the test in procedure part II.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Current | Speed | Angle  | $$τ\_{load}$$ | $$P\_{out}$$ | Efficiency | $$τ\_{induced}$$ | $$P\_{in }$$ |
| 2.6 | 1000 | 10 | 2 | 209 | 73% | 2.74 | 286 |
| 5.2 | 700 | 16 | 6 | 440 | 77% | 7.8 | 572 |
| 9.3 | 550 | 30 | 13 | 750 | 73.3% | 17.76 | 1023 |
| 12 | 450 | 41 | 25 | 1177 | 89% | 28 | 1320 |
| 15 | 350 | 48 | 40 | 1466 | 88% | 45 | 1650 |

IV- The torque-speed characteristics for both test (part I and part II)

The torque speed characteristic differs when R is set to zero or at maximum value. The graph below clears this point:

In fact, the value of the 1 ohm resistor has an impact on the characteristic. With the same torque we get lower speed since R adds to the field resistance Rf. So when Rf increases the value of the magnetization current decreases and this decreases the voltage which consequently decrease the torque.

V- Calculate the efficiency for the test in procedure part III. Plot on the same sheet the graphs of speed, motor current and efficiency.

In part III, the brake angle was set constant to 25 degrees corresponding to a constant current of 7.2 A approximately which corresponds to a load torque approximately 9.5 N.m.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Voltage (V) | Current (A) | Speed (RPM) | $$P\_{out}$$ | $$P\_{in}$$ | Efficiency |
| 100 | 7.2 | 600 | 597 | 720 | 83% |
| 90 | 7.2 | 530 | 528 | 648 | 82% |
| 80 | 7.2 | 450 | 448 | 576 | 78% |
| 70 | 7.2 | 400 | 398 | 504 | 78% |
| 60 | 7.2 | 300 | 299 | 432 | 70% |
| 50 | 7.2 | 250 | 249 | 360 | 70% |

We know that $e=KIw$ so when the speed increases, the voltage increase and vice versa.

VI- Comment on the stability of speed control with a series resistance. Explain why the efficiency stays relatively constant throughout the change in the voltage.

The stability of speed control with a series resistance, contribute in the power loss. But it is essential at no load.

It is also important to minimize the starting current which is usually high in DC series motors. The efficiency is the ratio of the output power to the input power so we have:

$$efficiency=\frac{P\_{out}}{P\_{in}}=\frac{τload\*w}{V\*I }=\frac{τload\*w}{Kφ w}=\frac{τload}{Kφ}=constant (PART III)$$

VII- Comment on the results and the graphs:

The voltage in the DC series motor is proportional to the flux according to the relation$ E=Kφw$. And we have that the torque is equal $(V x I)/w$ . So when the current increases the torque increases as noticed in the graph, and when the torque is constant the current is constant as analysed in Part III of the procedure. On the other hand we can also notice, that when the current increase (the torque increase) the speed of the motor decreases which is logical at constant voltage. Finally we can comment on the relation between the current and the output power. When the current increase the output power increase at constant voltage which is also logical according to the relation $P=V x I$.