

Electromechanics Lab EM4

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SUMMARY: This report explores a 3-phase induction motor's speed variation under different loads and supply frequencies. Results confirm proportional speed-frequency and inverse speed-torque relationships, with non-linear torque-slip correlation. Factors affecting slip deviation, like load variations, voltage fluctuations, motor design, age, wear, and environmental conditions, were discussed.

1. INTRODUCTION

This experiment uses a 3-phase induction motor common in industry. Unlike DC motors, it operates by creating a rotating magnetic field in the stator coils, driven by a 3-phase AC supply. The rotor's speed depends on the difference between its speed and the synchronous speed, induced currents generate torque. When under load, the rotor slows, increasing slip speed and torque until it balances the load. While many induction motors run at a constant speed from the mains supply, this experiment employs a variable-frequency controller for the motor, enabling variable speeds by converting single-phase AC to a variable-frequency 3-phase output.

Table 1: AC Test 2: The No-Load Speed Results

| Supply frequency f a (Hz) | Motor speed Nr (/min) |
|------------------------------|--------------------------|
| 0 | 0 |
| 10 | 294 |
| 15 | 443 |
| 20 | 592 |
| 25 | 741 |
| 30 | 889 |
| 35 | 1039 |
| 40 | 1190 |
| 45 | 1341 |
| 50 | 1488 |

1.1. Objectives

Here are the objectives laid out by the brief¹:

- (i) To find the relationship between the motor no-load speed and the supply frequency.
- (ii) To observe the variation in the motor speed with torque for a constant supply frequency.
- (iii) To observe the variation in the motor line current with torque for a constant supply frequency.

2. RESULTS

The results for the no load speed test AC 2 are displayed in Table 1 and in Fig 1.

The results for the effect of load test AC 3 are displayed in Table 2. This includes Shaft Torque, the variable; the current; the motor speed; and the Fractional Slip. In Fig 2, the motor speed is shown against shaft torque. In Fig 3, the current is shown against the same shaft torque. In Fig 4, the fractional slip is presented against shaft torque.

Table 2: AC Test 3: Effect of Load Results

| Shaft Torque (Nm) | Current (Amps) | Motor speed (rpm) | Fractional Slip N/A |
|----------------------|-------------------|----------------------|------------------------|
| 0.2 | 0.763 | 1490 | 0.008 |
| 0.3 | 0.753 | 1483 | 0.016 |
| 0.4 | 0.746 | 1478 | 0.026 |
| 0.5 | 0.739 | 1471 | 0.036 |
| 0.6 | 0.738 | 1465 | 0.047 |
| 0.7 | 0.735 | 1457 | 0.06 |
| 0.8 | 0.736 | 1449 | 0.072 |
| 0.9 | 0.737 | 1442 | 0.089 |
| 1 | 0.742 | 1436 | 0.108 |
| 1.1 | 0.745 | 1428 | 0.136 |
| 1.2 | 0.753 | 1422 | 0.174 |

3. DISCUSSION

In this section, this report discusses No Load Motor Speed Test Proportionality, the Effect of Load Torque on Motor Speed and the Effect of Load Torque on Fractional Slip.

¹Oner, M. (2020). Electromechanics Module Pack. The University of Sussex.

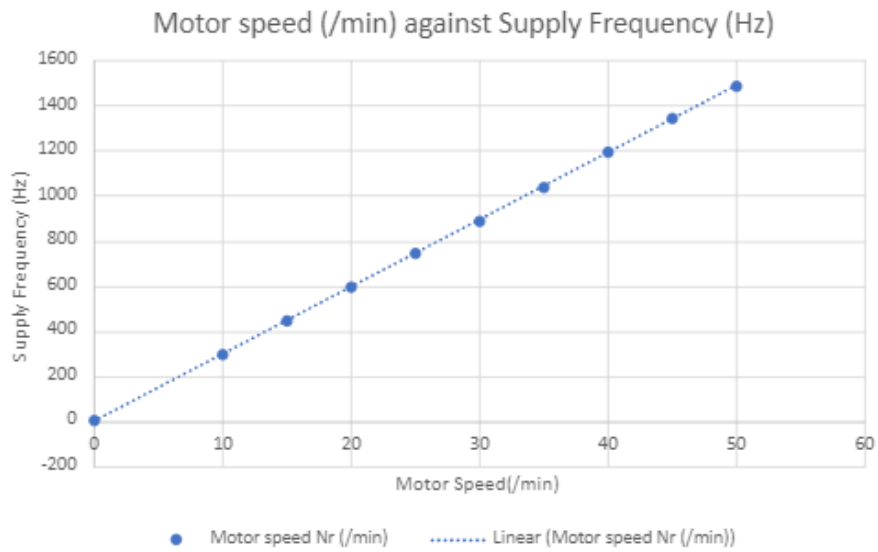


Fig. 1: Motor speed (/min) against Supply Frequency (Hz)

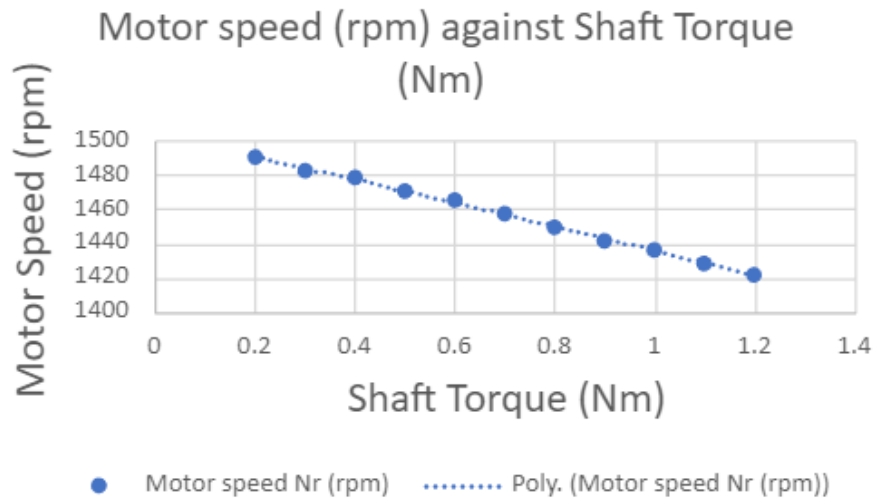


Fig. 2: Motor speed (/min) against Shaft Torque

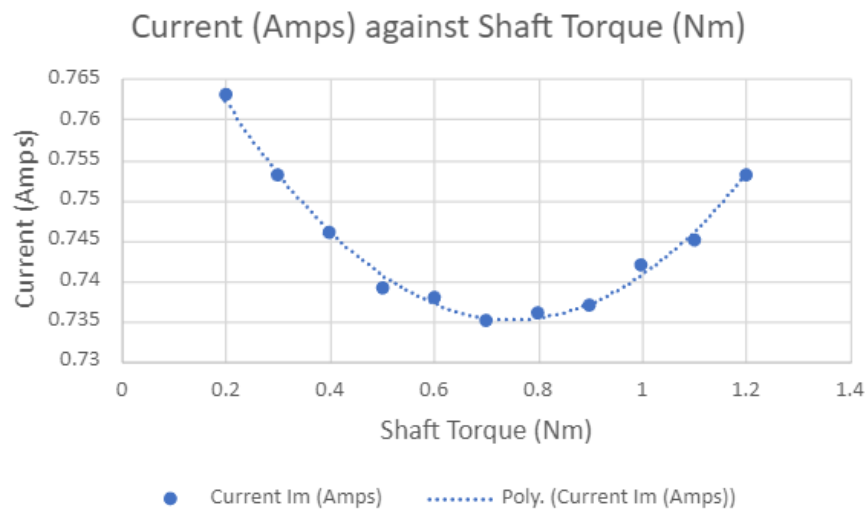


Fig. 3: Current (Amps) against Shaft Torque (Nm)

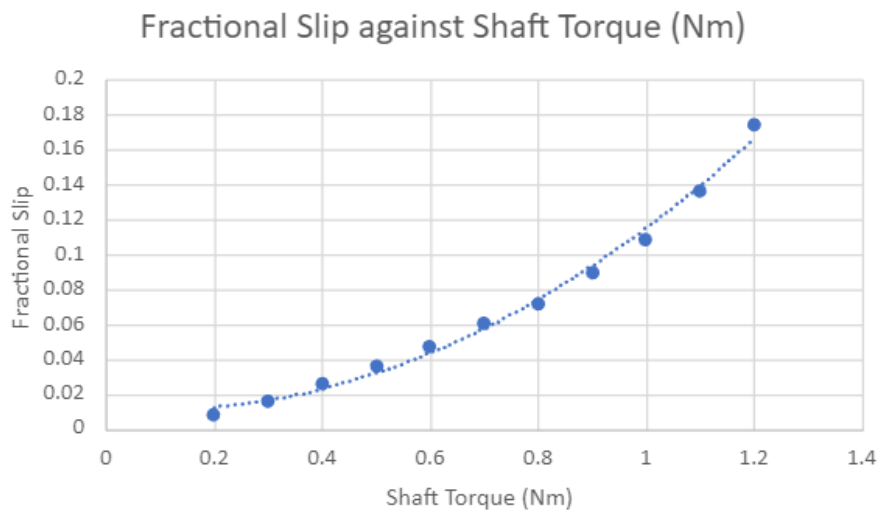


Fig. 4: Fractional Slip against Shaft Torque (Nm)

3.1. No Load Motor Speed Test Proportionality

The line of best fit goes through the origin and is constant which is what is expected. This shows that the motor speed is proportional to supply frequency.

3.2. Effect of Load Torque on Motor Speed

The data, as shown in Fig 2, shows that Motor Speed is inversely proportional to the Shaft Torque. In other words, as the shaft torque increases, motor speed decreases. This makes sense because the more load, or 'resistive force' the shaft has, the slower the motor will spin around said shaft.

It also makes sense that the line of best fit is first order. When a load is applied to the motor shaft, it resists the motion of the rotor, thus requiring more torque from the motor to maintain the rotation. As the load torque increases, the motor needs to generate more torque to overcome this resistance. This inverse relationship between torque and speed is often observed in the first-order approximation of the motor's behavior under varying loads.

3.3. Effect of Load Torque on Fractional Slip

In real-world conditions, the rotor speed of an induction motor always lags behind the synchronous speed because of fractional slip. Fractional slip is necessary for the rotor to induce currents and generate torque. The fractional slip should be directly proportional to the shaft torque because the shaft torque is inversely proportional to motor speed. However, it is not. The fractional slip is trending upwards in a second order manner.

This may be because of other factors real world factors not accounted for. These may include but should not be limited to:

3.3.1. Mechanical Load Variations

Changes in the mechanical load on the motor shaft can directly affect the slip. Higher mechanical loads lead to higher slips as more torque is required to maintain rotation. However, this should not be affected this experiment, since we did not change the physical mechanical load whilst changing the Torque loads.

3.3.2. Voltage Fluctuations and Frequency Variations

Variations in the supply voltage can affect the motor's performance. Lower voltages can lead to

higher slips due to reduced torque production. This may have affected the experiment and would be down to the equipment providing irregular voltages. The Same problem could be due to frequency. Deviations from the nominal frequency of the power supply can impact motor performance. Lower frequencies can result in higher slips and vice versa.

3.3.3. Motor Design and Construction

Different motor designs and constructions can have varying efficiencies and operating characteristics, leading to differences in slip.

3.3.4. Age and Wear

As motors age they may get wear and tear, their performance may degrade, leading to deviations from theoretical slip values.

3.3.5. Environmental Conditions

Factors such as humidity, dust, and altitude can affect motor performance and slip. Motor temperature can also affect its resistance and therefore its performance. Higher temperatures can increase resistance and decrease efficiency, potentially leading to higher slips.

It is also worth noting that we changed motor halfway through this experiment and that may have affected the results. However they were the same make and age and remained in the same location.

4. CONCLUSION

This experiment confirmed theoretical expectations regarding the behavior of 3-phase induction motors. It demonstrated the proportional relationship between motor speed and supply frequency, and the inverse relationship between speed and torque. However, deviations in fractional slip indicate additional factors affecting motor performance. The discussion talked about mechanical load variations, voltage and frequency fluctuations, motor design and age, and environmental conditions affecting fractional slip. Further research can improve understanding of these specific motors.