

Investigating Fatigue as a Limiting Factor in Electric Servo Motors for Lightweight Robotic Applications

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Introduction

Motors of all size scales, from molecular motors to jet engines, have been found to scale in torque production proportional to their mass with a maximum force density of 57 N/kg.^{1,2} Despite the differences in force production mechanisms, all motors seem to share the same fundamental limitation, with the current proposed theory suggesting that fatigue is the main factor limiting force production.³ Our project aims to test this theory by observing the fatigue of electric servo motors over a range of stress and identifying the components limited by fatigue. Understanding these limitations could lead to the development of lighter and stronger motors for lightweight robots and exoskeletons that amplify human capability.

Methods

Rotary servo motors were connected to an Arduino Uno microcontroller board and a DC power supply with a constant voltage of 4.8 volts. Motors were secured to a base to prevent movement during operation. Loads on the motor arm were progressively increased to observe motor failure. The time from initial stress to failure was recorded to determine how the motors respond to fatigue.

Results

To create an S-N diagram describing material fatigue, we first determined the stress required to achieve failure after one cycle. Motors were initially stressed at a starting load of 3.1 kg, based on previous experiments, and steadily increased to 6.1 kg. If the motor completed multiple cycles at a certain weight, the ultimate stress was deemed greater, and the weight was subsequently increased. At 6.1 kg, the motor

stalled but remained operational with no signs of mechanical damage, suggesting that the limitation of force production in these motors was not fatigue.

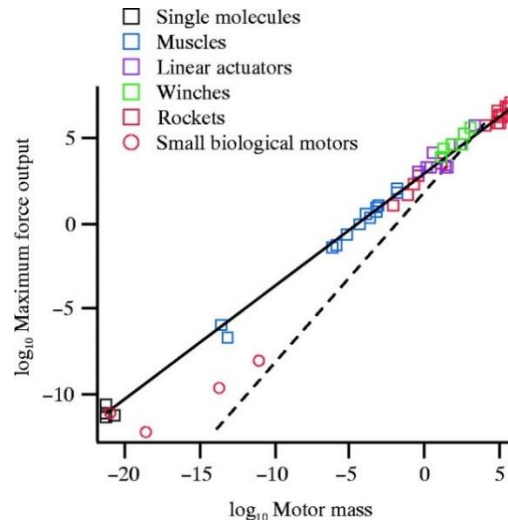


Figure 1. The motor force as a function of motor mass for rotary motors identified by Marden and Allen.¹

Conclusion

Our testing indicates that neither fatigue nor mechanical failure are the main limitations for electric servo motors. Future studies should investigate other potential limitations of force production in electric motors, such as thermodynamic constraints⁴ or other mechanical limitations.^{5,6}

References

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