Development of Supination-Pronation Tremor Reduction Device on the Principles of Tuned Mass Damping

Bai Lab

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Motivation

The motivation behind this research project is to develop a passive device that effectively reduces supination-pronation tremors through the principles of tuned mass damping.

Introduction

Supination-pronation tremors are involuntary, rhythmic movements of the forearm. It affects 3-4% of the population and can severely impact the quality of life for those affected by this condition. Current treatment options for this condition are limited and can come with significant side effects. As such, alternative solutions that are effective and safe are greatly needed.

One possible solution is the application of tuned mass damping (TMD). TMD involves the use of a mass-spring-damper system to absorb and dissipate energy from vibrations. It has been successfully employed in real-world scenarios, such as mitigation the effects of earthquakes on structures. The principles of TMD have the potential to be adapted for tremor reduction.

The objective of this research is to explore the effectiveness of TMD on supination-pronation tremor reduction. This research will contribute to our understanding of the potential benefits of TMD for tremor reduction and may unfold new avenues for the development alternative treatments for patients with tremors.

Data

Theory

A TMD system is designed to vibrate out of phase with the arm's natural frequency, resulting in the dissipation of energy and reduced vibration amplitudes. Damping is done using Eddy current effect involving movement of magnetic field in the presence of a conducting material. The device design includes magnets held by springs on both ends and covered by an aluminum plate. The device base rotates with the arm, and the magnet has freedom to move inside.

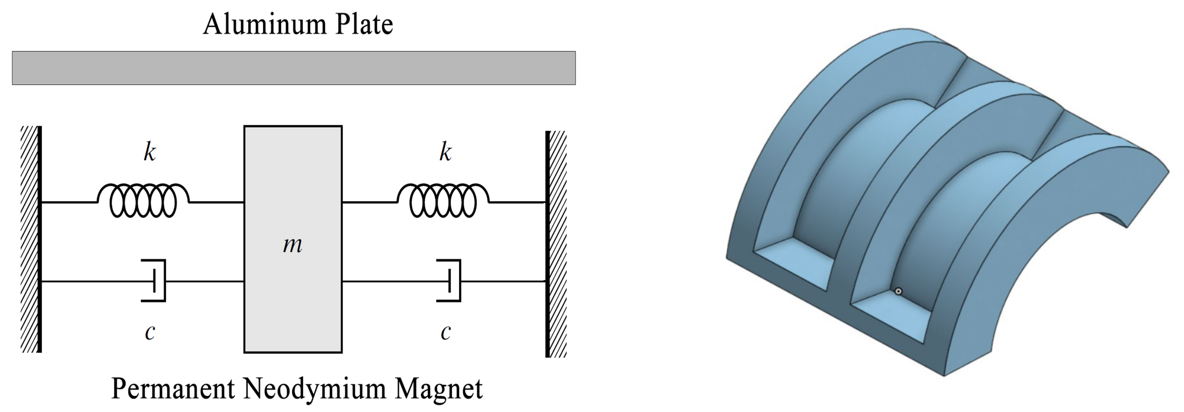
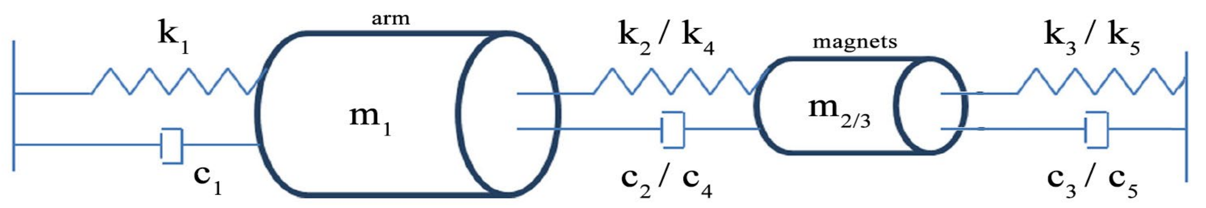


Figure 1: Left) Diagram of the magnet spring system showing the placement of the springs and conductive aluminum plate. Right) Casing for the tremor reduction device

Equations



$$m_1\ddot{\theta}_1 = -k_1(\theta_1-\theta) - c_1(\dot{\theta}_1-\dot{\theta}) + (k_2+k_3)(\theta_2-\theta_1) + (c_2+c_3)(\dot{\theta}_2-\dot{\theta}_1) + (k_4+k_5)(\theta_3-\theta_1) + (c_4+c_5)(\dot{\theta}_3-\dot{\theta}_1)$$

$$m_2\ddot{\theta}_2 = -(k_2+k_3)(\theta_2-\theta_1) - (c_2+c_3)(\dot{\theta}_2-\dot{\theta}_1)$$

$$m_3\ddot{\theta}_3 = -(k_4+k_5)(\theta_3-\theta_1) - (c_4+c_5)(\dot{\theta}_3-\dot{\theta}_1)$$

Figure 2: A two degrees of freedom model of a dynamic vibration absorber (m_1 and m_2) attached to the main structure (M). (k) and (c) values represent different spring and damping systems.(θ) is the distance moved in circular motion by each mass.

Experimental Setup

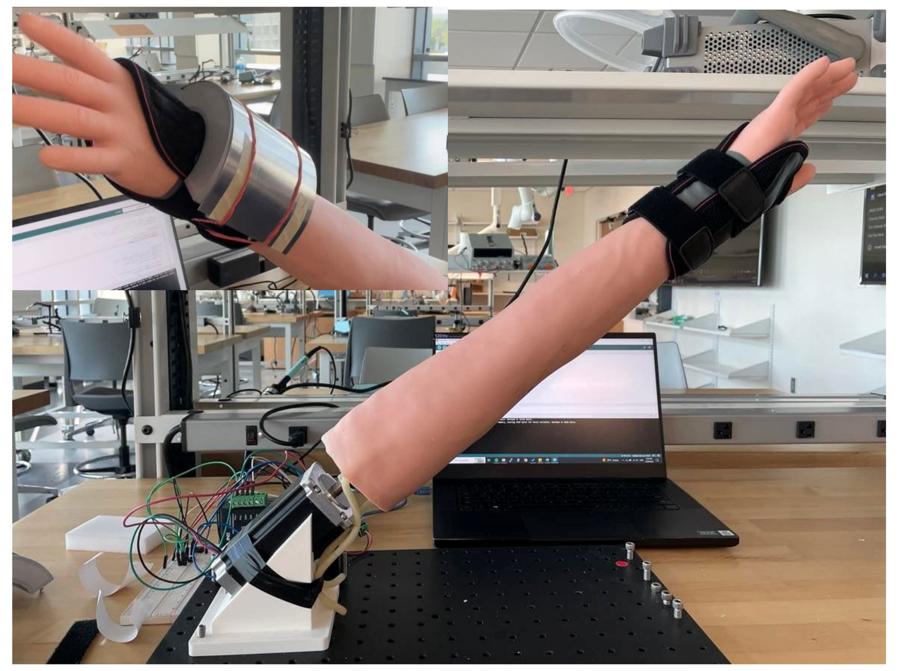


Figure 3: Simulation of supination-pronation tremor on a forearm

The experimental setup involved connecting an arm to a servo motor to simulate tremors and analyzing the amplitude of arm vibration with and without the TMD device. A video camera recorded the arm movement and was analyzed using color tracking in MATLAB to calculate the degree of rotation over time.

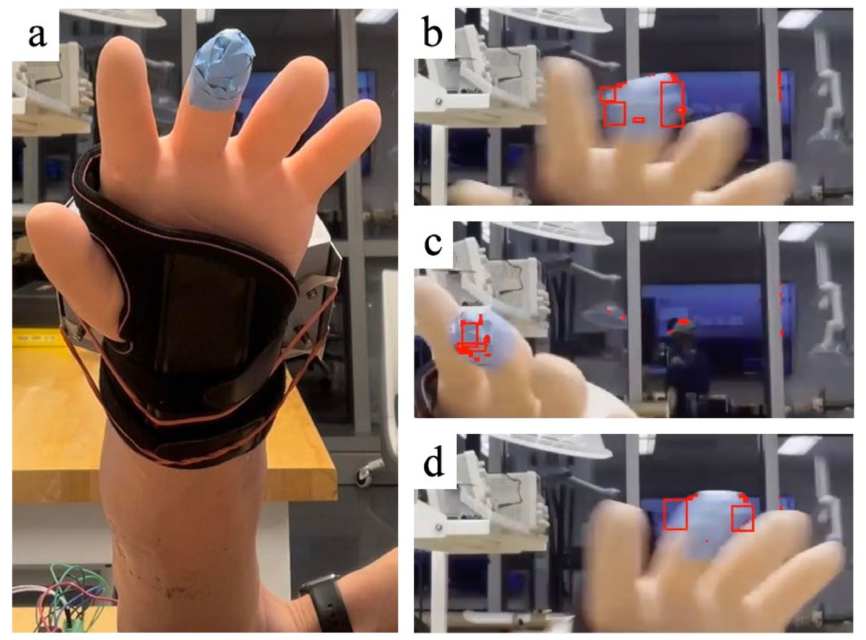


Figure 4: Vibration amplitude analysis method using color tracking on the arm's finger. Specific color was analyzed frame by frame and x and y coordinates were extracted.

Results

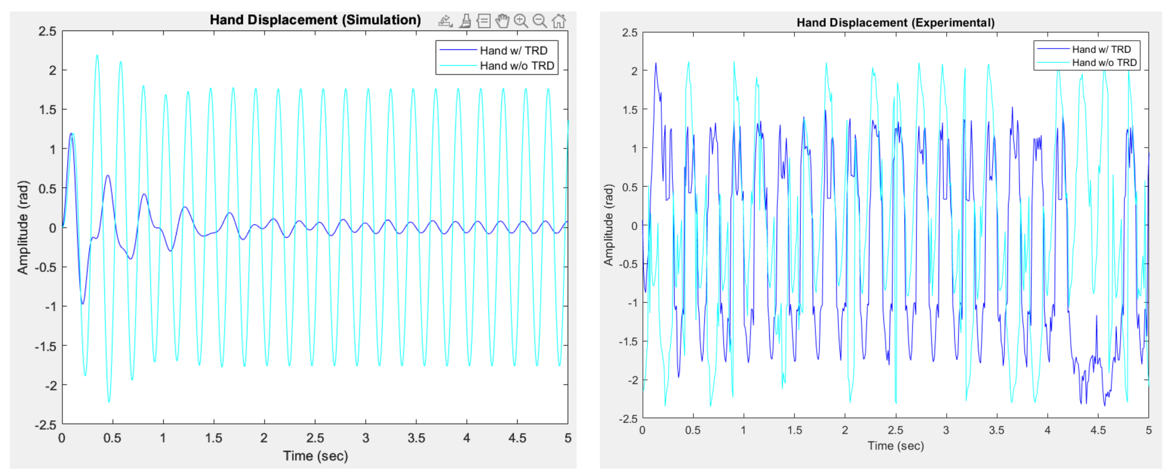


Figure 5: Left) Simulation of forearm supination-pronation tremor with and without the TMD device. Right) Experimental recording of forearm supination-pronation tremor with and without the TMD device.

Magnet mass and strength and spring elasticity was optimized to provide the most effective dampening to 4 Hz vibration of forearm, the most common tremor frequency. A simulation of such parameters was run on MATLAB over several iterations, showing an average of 82% reduction in tremor amplitude. Experimental results showed an average 35% reduction in tremor amplitude. Additionally, the device provided more consistent oscillations compared to not using the TMD device.

Conclusions

While the experimental results were not as effective as predicted, the consistent decrease in tremor amplitude shows promise for the field of research in reducing tremor symptoms. Further testing is needed to confirm the effectiveness of tuned mass damping.

References

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