Proceedings of the International MultiConference of Engineers and Computer Scientists 2018 Vol II
IMECS 2018, March 14-16, 2018, Hong Kong

Damper Glove for Hand Tremor

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Abstract— **Assistive devices for people that suffer from essential hand tremors have been developed and made available in the market. However, most of these devices only focus on a single purpose, or are rather heavy and bulky which could be uncomfortable for the user. Using the concept of dampers and electromagnetics, this research aimed to create a small damping system that is portable, wearable and capable of damping hand tremors. The system is composed of solenoids as actuators, magnetic weight as end-effector, a 6DoF gyro-accelerometer sensor for motion reading, and a microcontroller for processing and controls. The system is capable of detecting direction of motion and can distinguish between tremor and a deliberate motion. It is observed that as the driving frequency increases, the amplitude of vibration produced also increases. Using open-loop system test, it is observed that the system is able to reduce the amplitude of the tremor, and the significance of the effect is relative to the severity of the tremor in terms of amplitude.**

Indexed Terms—**damper glove, linear damper, hand tremors**

I. Introduction

TREMOR is an involuntary rhythmic movement of muscles. It is generally caused by problems in parts of the brain that control muscle movements [1].

According to the National Health Service of United Kingdom (UK), everyone has a very minor tremor [2]. For example, hands slightly shake when held out or even when at rest. These tremors are normal tremors. Sometimes, these tremors become more noticeable, particularly in older people, and it's often caused by adrenaline rush, anger, anxiousness, and when under pressure.

An example of an abnormal tremor is essential tremor. Essential tremor is more severe than normal tremor. It can affect the hands, arms, head, face, voice, trunk, and legs [3]. To some, it may be mild and non-progressive, to others however, the tremor slowly progresses and becomes a hindrance to performing certain tasks, or even daily tasks - such as eating.

Assistive devices for people that suffer from essential hand tremors have been developed and made available in the market [4], examples of which are: the S'up spoon and Liftware – which ease the process of eating. However, these devices only focus on a single purpose.

Dr. Krista L. Madere, an occupational therapist in Baton Rouge, Louisiana, sought to solve this issue by developing the Readi-Steadi glove. It is a glove that uses weights to help dampen the tremor in the hands [5]. However, the number of weights embedded in the gloves is proportional to the severity of the tremor experienced that could prove heavy and uncomfortable for the user.

Manuscript received January 8, 2018; revised January 30, 2018. This Work was supported in part by the Robotics and Automation Laboratory in the Electrical and Electronics Engineering Institute of the University of the Philippines, Diliman.

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II. Objectives

The main objective of this research is to create a simple, portable and wearable device that could help dampen the tremor experienced in the hands.

The following are considerations in the design of the damper.

- With size considerations to assure that the mechanical damper will be portable and comfortable to wear, the motion of the magnetic weight must have a considerable effect on the sense of balance of the hand.
- The hand is most often in motion; thus, it is important to distinguish a deliberate from that of an involuntary movement. The magnitude and frequency of oscillation must be determined for distinction.
- Tremors have variable magnitude and frequency. So, for the damping mechanism to be effective it must react to the tremors real-time; hence, the necessity to predict the motion of the tremor. This will be used in determining which coil to actuate the magnetic weight.

III. Methodology

A. Mechanical Model

The damper system hardware was designed to be portable and light-weight yet able to generate significant vibrations. It consists of a magnetic weight as shown in Fig. 1; two electromagnetic coils attached on the mounting case as shown in Fig. 2; and IMU, and a microcontroller.

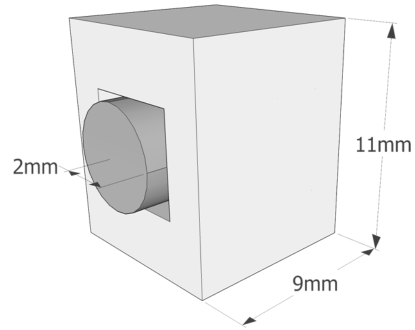

Fig. 1. Mass damper model. The mass damper was 3D-printed and attached on the left and right faces were neodymium magnets (NdFeb D5mm x 2mm N42) with B = 0.507 T, both North exposed. It was restricted to move along a single axis (y-axis).

The solenoids were designed such that it has the same magnetic field as the mass damper. Using Ampere's Law,

$$B = \frac{\mu N I}{L} \tag{1}$$

it was computed that with 1mm solenoid length, aluminum core, and assumed driving current $I = 0.5A$, the number of windings were 672 turns (rounded to 700 turns). The coils were wound using a manual hand coil winding machine NZ-5 Dual Purpose Manual Coil Winder.

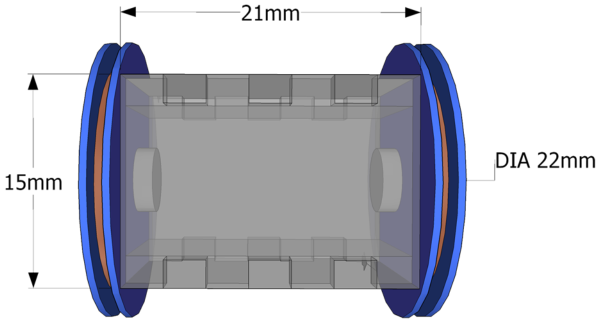

Fig. 2. Mounting case model. The mounting case is 21mm x 21mm x 15mm, laser-cut from a 2mm thick acrylic sheet. The two solenoids were attached to the left and right of the mounting case.

An Adafruit 6DoF IMU breakout board (3DoF gyro meter + 3DoF accelerometer) was placed beside the damper. The microcontroller used was an Arduino Uno. Both the sensor and the damper were mounted on a foam board, that was mounted to the backside of the glove.

The solenoids were always driven with 50% duty cycle. If the current was following the direction as shown in Fig. 4, the mass damper would move towards the right.

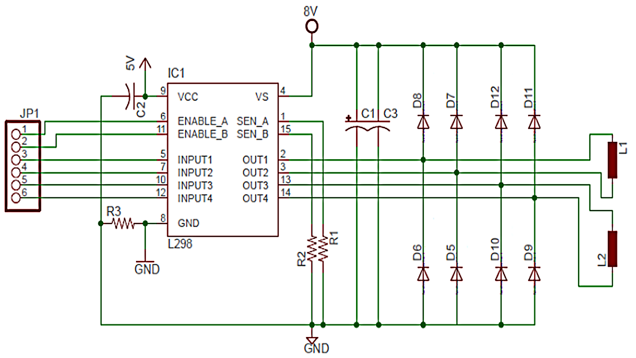

Fig 3. Dual H-Bridge Driver Schematic. An L298 dual H-bridge was used to drive the pair of electromagnetic coils (i.e. right and left). The microcontroller would be sending TTL signals on the pair of coils on the opposite direction of the detected motion, and with frequency dependent on the frequency of the hand tremors.

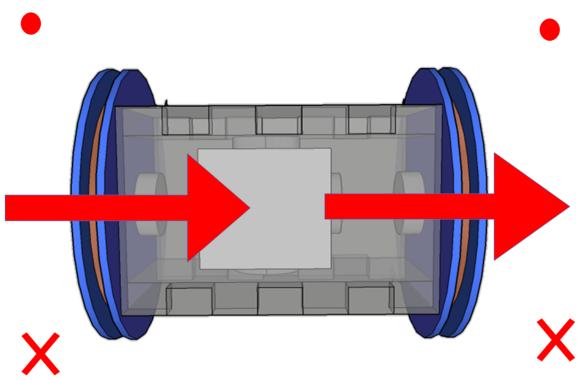

Fig. 4. Actuation Direction. ● denotes that the current goes out of the page; while ✕ denotes that the current goes into the page; and ➞ denotes the direction of the magnetic field.

B. Software Design

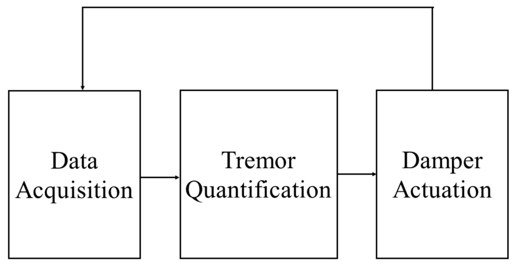

Fig. 5. Software Implementation Block Diagram. The software implementation was divided into three parts: a) data acquisition, b) tremor extraction, and c) actuation.

The processing time of the software must be considered for a more effective result.

1) Data Acquisition

The MPU6050 IMU breakout board communicates with the Arduino microcontroller through the I2C peripheral. The IMU gives the raw angular acceleration and raw angular position. The accelerometer offset was set by factory default: a = 1688; while the application Processor was used to calibrate the gyro: x =-10; y = 76; z = -85.

The function used for analysing the data measured by the IMU Sensor is based on the multiplication of quaternions [6]. The general form for quaternion is:

$$Q = a + b\boldsymbol{i} + c\boldsymbol{j} + d\boldsymbol{k} \qquad (2)$$

where $a, b, c,$ and d are all real numbers. This was to represent the raw data into 3D reflections. a is the angle of rotation about the axis represented by $b, c,$ and d.

The quaternion in terms of axis-angle is represented by the form:

$$Q = cos(^a/_2) + \left(b \times sin(^a/_2)\right)\boldsymbol{i} + \left(c \times sin(^a/_2)\right)\boldsymbol{j} + (d \times sin(^a/_2))\boldsymbol{k} \qquad (3)$$

Outputs are in the angular forms of Roll, Pitch, and Yaw, as shown in Fig. 6.

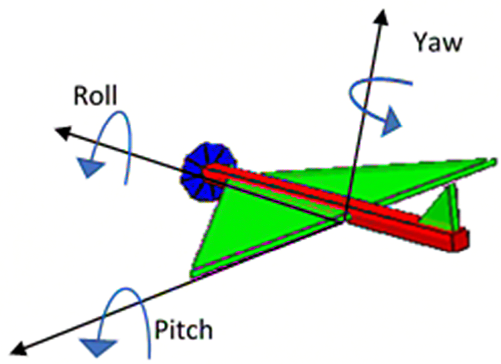

Fig. 6. Orientation.

The amount of time spent in fetching and calculating the gyro and accelerometer data took about 15 milliseconds, so due to hardware limitations, the sampling frequency (f_s) was about 67 Hz.

2) Tremor Estimation

A lapse of 30 seconds was used for initializing and calibrating the system and another 30 seconds for frequency

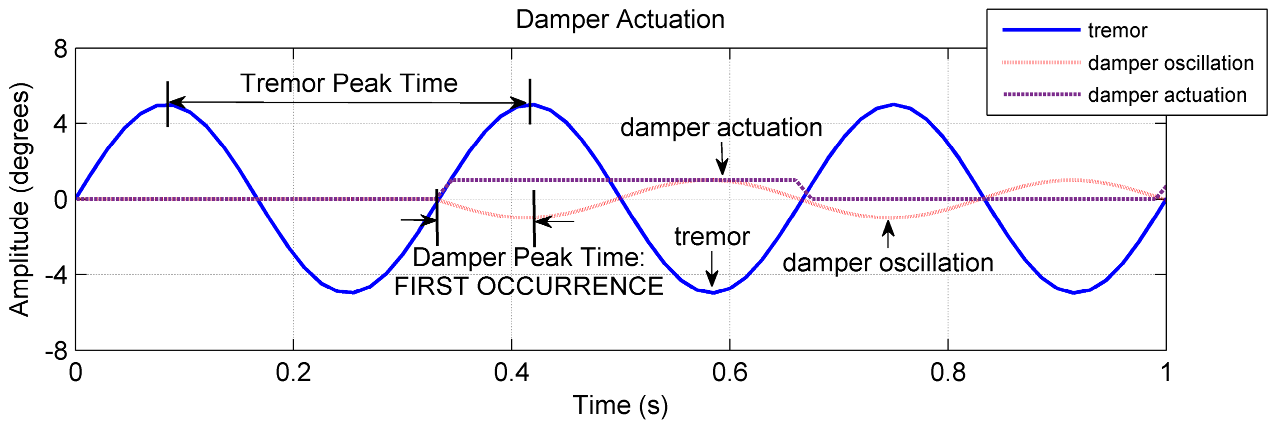

Fig. 7. Theoretical Peak Reading. This is the ideal case scenario for actuation. Tremor Peak Time is the time difference between the occurrence of the first two peaks. The Damper Peak is the time when the oscillation caused by the system first peaks.

analysis. The number of peaks (local maxima) found at a sampling set was assumed to be the tremor frequency (f_c).

If $2Hz \le f_c \le 15Hz$ still considered as tremor [7].

If $0.5^\circ \le \Delta\theta/\Delta t \le 2^\circ$ or $-0.5^\circ \ge \Delta\theta/\Delta t \ge -2^\circ$ considered as tremor, by experimentation. Only the θ_r was used for reading and analyzing the tremor signal. It was the assumed amplitude of oscillation of the tremor.

3) *Actuation*

If $0.5^\circ \le \Delta\theta/\Delta t \le 2^\circ$, then tremor direction is right. Else if $-0.5^\circ \ge \Delta\theta/\Delta t \ge -2^\circ$, then tremor direction is left. The microcontroller will then turn on the electromagnetic coil in that direction, (i.e. tremor direction is left, drive left solenoid to push damper to the right). The mass damper would be capable of moving linearly along y-axis. The actuation must be fast occurring and, if necessary, recurrent to provide a significant vibration that will negate the natural tremor.

The time of actuation of the damper was computed by inferring the next peak occurrence of the tremor through the calculated f_c and the first peak occurrence effected by the damper which was calculated during the damper characterization phase. Ideal case scenario is shown in Fig. 7.

IV. Test Results

A. *Tremor Data*

The following data were taken using the glove with the MPU6050 module attached while imitating a person with tremor. These data were analyzed using MATLAB Fourier tool to get the spectral peak and determine whether it is within range of what is considered as a tremor. And filtered with a 2nd order Butterworth bandpass filter to get the tremor signal. Sample signal at 5Hz is shown in Fig. 8.

TABLE I
Tremor Signal Summary Table

Tremor Signal	Frequency (Hz)	Amplitude (degrees)		
		Low	High	Peak to Peak
1	5.0	-2.55	2.55	5.10
2	3.0	-5.53	5.53	11.07
3	4.5	-1.78	1.78	3.56
4	5.5	-3.14	3.14	6.29
5	5.5	-1.20	1.20	2.40

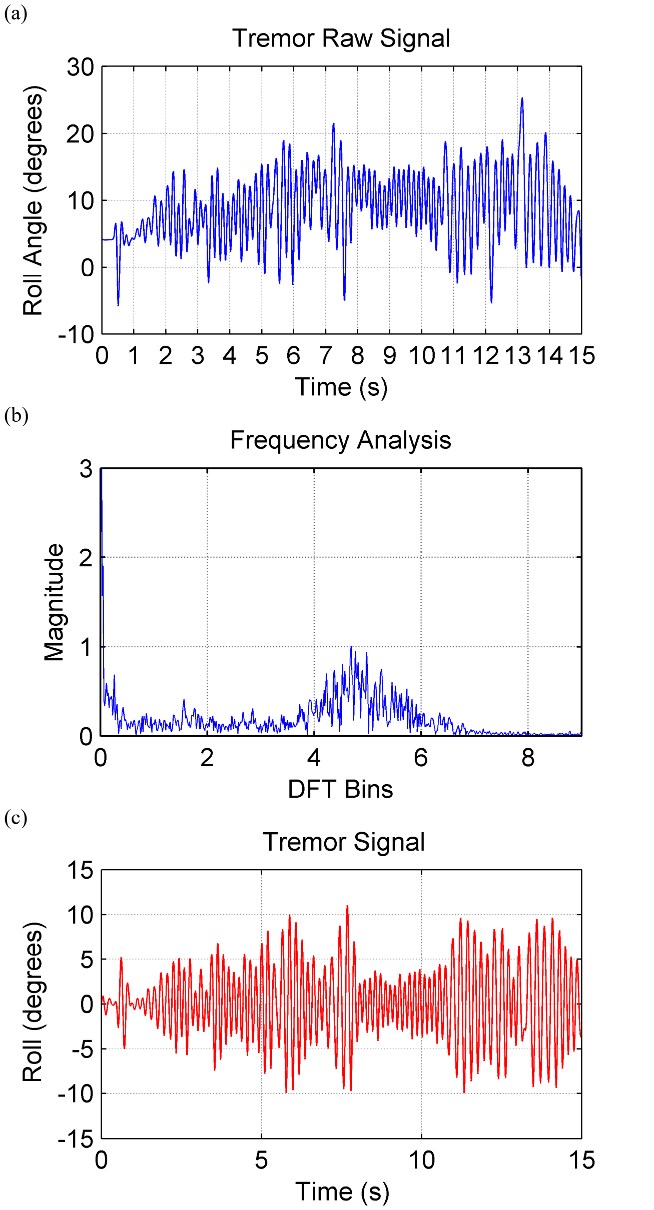

Fig. 8. Sample Tremor Signal 1 at 5Hz. (a) Raw signal from hand raised shoulder-level. (c) Spectral peak at 5Hz. (d) Extracted tremor signal.

B. *Characterizing the Damper*

A cylinder tube was placed inside the glove acting as the base to get the vibrations created by the damper. The damper was actuated, (always starting from the left) with frequency (f_c) 0.5 Hz to 16Hz with a step of 0.5Hz while simultaneously

ISBN: 978-988-14048-8-6
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

gathering θ_r. Ten trials were done for each frequency. The computation was done by sets of samples within each pulse of actuation. The number of samples in every actuation is

$$m = \frac{1}{f_c} \times f_s. \quad (4)$$

This is necessary for the computation of the first peak occurrence.

Notice, from TABLE II, that as the frequency increases, the amplitude of vibration also increases. The correlation between the frequency and peak-to-peak amplitude of vibration is calculated to be 0.8022. Also, as the frequency increases, the number of oscillations within each pulse of actuation approaches to 1.

TABLE II
DAMPER CHARACTERIZATION AT VARIOUS FREQUENCIES

Frequency (Hz)	AMPLITUDE (degrees)			PEAK TIME (s)		FIRST PEAK OCCURRENCE (s)
	LOW	HIGH	PEAK TO PEAK	LOW	HIGH	
2.0	-0.09	0.08	0.18	0.11	0.11	0.0294
2.5	-0.10	0.10	0.21	0.12	0.12	0.0320
3.0	-0.15	0.15	0.30	0.12	0.13	0.0206
3.5	-0.13	0.13	0.26	0.11	0.13	0.0256
4.5	-0.23	0.22	0.46	0.13	0.11	0.0312
5.0	-0.23	0.24	0.47	0.13	0.12	0.0337
5.5	-0.21	0.20	0.42	0.11	0.11	0.0292
6.0	-0.19	0.16	0.35	0.10	0.10	0.0317
6.5	-0.19	0.14	0.33	0.09	0.09	0.0355
8.5	-0.09	0.12	0.21	0.07	0.07	0.0427
9.0	-0.10	0.11	0.21	0.08	0.08	0.0455
9.5	-0.13	0.10	0.23	0.07	0.07	0.0464
10.0	-0.30	0.48	0.78	0.12	0.12	0.0645
10.5	-0.26	0.35	0.61	0.10	0.10	0.0544
11.0	-0.21	0.33	0.55	0.11	0.11	0.0571
11.5	-0.53	0.57	1.11	0.13	0.13	0.0692
12.0	-0.52	0.55	1.07	0.13	0.13	0.0679
12.5	-0.51	0.65	1.17	0.13	0.13	0.0680
13.0	-0.47	0.69	1.16	0.13	0.13	0.0677
13.5	-0.41	0.43	0.84	0.13	0.13	0.0667
14.5	-0.43	0.37	0.80	0.11	0.11	0.0559
15.0	-0.44	0.39	0.83	0.11	0.11	0.0552

TABLE III
DAMPING EFFECT SUMMARY

TREMOR	TREMOR AMPLITUDE w/o DAMPER (degrees)	TREMOR AMPLITUDE w/ DAMPER (degrees)	DIFFERENCE (degrees)	PERCENTAGE (%)
1	5.1	4.9668	0.1332	2.6118
2	11.072	10.453	0.620	5.5997
3	2.4073	3.1554	0.4045	16.8031
4	6.2915	5.9843	0.3072	4.8828
5	2.4073	1.8763	0.5310	22.0579

C. Summing the Tremor and Damper Data

The tremor and the damper signals were overlapped as shown in Fig. 7.

TABLE III show the damping effect at the first peak alignments. Results show that the damper system helps reduce the amplitude of the tremor. The effect at high amplitude is slight while the effect at low amplitude is high.

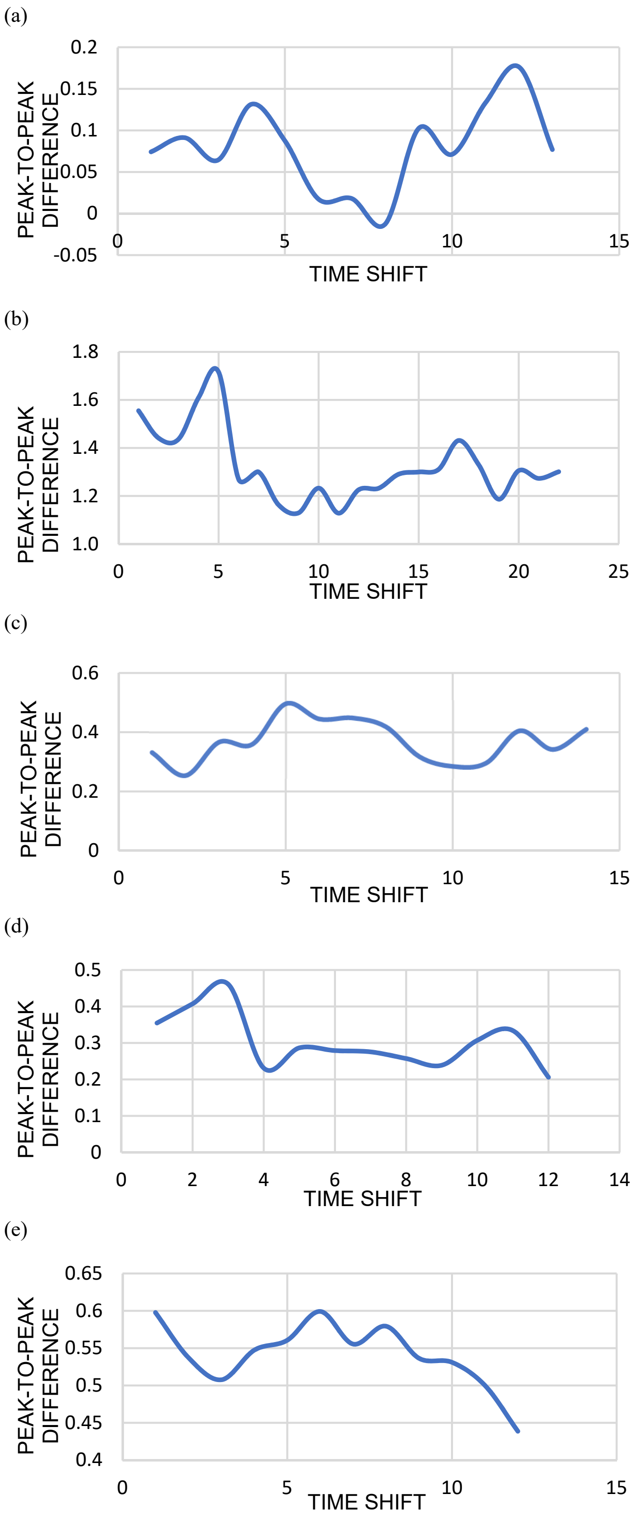

Fig. 9. Time-Shifted Peak Difference. (a) Tremor signal 1 at 5Hz with amplitude 5.10°, first peak alignment is at time shift 11. (b) Tremor signal 2 at 3Hz with amplitude 11.07°, first peak alignment is at time shift 4. (c) Tremor signal 3 at 4.5Hz with amplitude 3.56°, first peak alignment is at time shift 12. (d) Tremor signal 4 at 5.5Hz with amplitude 6.29°, first peak alignment is at time shift 10. (e) Tremor Signal 5 at 5Hz with amplitude 2.41°, first peak alignment is at time shift 11.

ISBN: 978-988-14048-8-6
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

D. Summing the Tremor and Time-Shifted Damper Data

The damper signal is time-shifted m times by $1/f_s$ to also observe if there is a trend with regards to the alignment of peaks of both signals.

As shown in Fig. 9, there was no definite trend regarding the time-shifted damping effect. This was due to the variability of the amplitude and the difference between the peak time of the two signals. But 3:5 of the test cases show that the first peak alignment was the more effective in reducing the tremor amplitude.

V. Conclusion and Recommendation

The system is simple, portable and wearable. The mass damper produces vibration. It has a variable frequency which allows the system to adapt to the severity of the tremor.

It is capable of determining whether the motion is caused by a tremor or is a deliberate move by the user based on $\Delta\theta_r/\Delta t$ and frequency. If slope is positive, the damper moves to the left, else if the slope is negative, the damper moves to the right.

The correlation between the frequency and peak to peak amplitude of vibration is 0.8022. As the frequency increases, the vibration amplitude also increases, while the number of oscillations per actuation approaches 1.

The test results show that the system is able to reduce the amplitude of the tremor. The significance of the damping effect depends on the tremor amplitude. Additional tests with varying tremor severity and online tests with a person with hand tremor is recommended to further assess the effectivity of the system.

It is important to note how fast the microcontroller process and react to the system. A faster microcontroller or a more optimized function is recommended.

The weight of the mass damper must have a significant effect in the amplitude of resulting vibrations. A further study is recommended.

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