Anti-shaker Simulation for Arm Tremor

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Abstract. This paper presents a method for designing tremor suppression system that can reduce shaking in tremor. The design of the anti-shaker consists of a slider and a reciprocating device that counters the oscillatory movement. The oscillations according to tremor are considered as harmonic disturbances. With the use of LabVIEW and logical programming for PID controller, tremor suppression can be achieved efficiently. The results show that the amplitude, frequency, and weight which are the adjustable variables of the anti-shaker can be put to counter the shake symptom of tremor.

Keywords: Tremor suppression, PID controller, Simulation, Reciprocating, Arm Tremor

1. Introduction

Tremor is defined as the rhythmic, shaking movement and is observed at a relatively fixed frequency and amplitude [1], [4], [6], [10]. It is found that the tremor frequency range is between 4 to 12 Hz [3]. The causes of tremor include stress, anxiety, fatigue, alcohol, use certain drugs and other [9]. Physiological tremor is considered a ubiquitous property of the neuromuscular system that can be recorded from all limb segments under resting, postural or movement conditions [5]. There are two types of tremor always seen on the Parkinson's (PD) patients, resting and postural tremor. Resting tremor occurs when the muscles stay relax and limbs are fully supported. Postural tremor appears when a part of the body is maintained in a fixed position and may also persist during movement [2].

Resting tremor occurs on the range of 3-7 Hz, occurs in up to 75% of individuals with PD. Postural tremor is usually observed between 5 and 12 Hz and is symptomatic at around 60% of PD patients. Because the underlying Physiology of pathological tremor is not well understood, existing physical and drug therapies have not been successful in tremor treatment, giving rise to the need for alternative approaches to the problem of tremor suppression.

Rui et al. [8] proposed an orthosis that can dynamically suppress pathological tremor, by applying viscous damping to the affected limb in a controlled manner. Recently, a wearable orthosis, which can adapted to each configuration of each joint of the upper limb has been proposed [7]. The orthosis can be used as a treatment for essential tremor patient.

This paper proposes a general method for the design of tremor suppressing via reciprocating system using PID controller. The idea inspired by the work of [4] which proposed the analysis performed based on frequency and amplitude parameters. The fast Fourier transform(FFT) and higher-order spectra were used to extract frequency parameters. The discussion in this paper is limited to only simulation and programming.
2. Materials and Methods

The objective was to design a way to suppress arm tremor by using an anti-shaker. In Fig. 1, the full model of the anti-shaker consists of two sliders, a mass bar, a circle disk, and a motor as seen in the Fig. 2.

The anti-shaker is mounted on the arm bar which is a part of a wearable orthotic device. Fig. 3 shows how the device roughly looks like after the design.

![Fig. 1: Anti-shaker.](image)

![Fig. 2: The exploded view: 1. motor, 2. disc, 3. mass bar, 4. slider, 5. arm bar.](image)

![Fig. 3: Orthotic device: 1. Upper arm, 2. Elbow pivot, 3. Lower arm, 4. Anti-shaker.](image)

The arm movement of tremor patient usually consists of actual arm movement and tremor. Frequency of actual arm movement is usually low (not more than 3Hz) and might not even be in harmonic form. On the other hand, frequency from the tremor is normally higher with the range between 4 – 12 Hz. This fact can help to filtering out the amplitude and frequency of tremor that need to be suppressed. To extract the tremor signal, high-pass filter is used at 3 Hz cut-off frequency as shown in Fig. 4. This tremor signal acts similar to a harmonic waveform with amplitude and frequency properties. In order to subdue this signal, PID controller is used which will be discussed later.

![Fig. 4: Filtering of arm movement signal.](image)
By using MSC software, ADAMS-view, the properties of waveform generated by anti-shaker can be analyzed. Amplitude can be adjusted as the slider moves along the arm bar. The further the anti-shaker is to the elbow, the higher amplitude value can be as in Fig. 5. On the other hand, controlling the speed of motor which drives the reciprocating system can achieve the required frequency.

The mass bar in the reciprocating system can be attached with additional mass in order to tune the amplitude for different arm weight. The more mass, the more amplitude the anti-shaker can produce.

In order to check the signals of arm movement and tremor, the spectral measurement block in LabVIEW is used as seen in Fig. 6.

The tremor signal can be modeled in state space form as following;

\[
\theta(t) = A\sin(\omega t)
\]
\[
\theta(s) = \frac{A\omega}{s^2 + \omega^2}
\]

With input \(U(s)\),

\[
s^2\theta(s) + \omega^2 \theta(s) = A\omega U(s)
\]
\[
\dot{\theta} = -\omega^2 \theta + A\omega U
\]
Let

\[ x_1 = \theta \]
\[ x_2 = \dot{\theta} \]

Then,

\[ \begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -\omega^2 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ A\omega \end{bmatrix} u \]
\[ y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \]

There are actually two inputs to the system which are force from the anti-shaker \( (u_1) \) and distance of the anti-shaker to elbow \( (u_2) \). From the state space form, the input \( (u) \) can be expressed as a multiple of \( u_1 \) and \( u_2 \). \( u_1 \) is the frequency driven by the anti-shaker, and \( u_2 \) is the amplitude obtained from sliding the anti-shaker along the arm. This can lead to a nonlinear system since there is a multiplication of inputs. In order to handle this problem, we can use only \( u_1 \) as the input to take care of the frequency part. The amplitude of tremor can be obtained from the test of individual patient before hand. In the implementation, adjusting the distance of anti-shaker is needed first to fit the appropriate amplitude range of the individual patient before tremor suppression process.

The block diagram of PID controller is shown in Fig. 7. The reference signal can be seen as the actual movement of arm. Fig. 8 shows the simulation results of the tremor signal with 10 Hz frequency and amplitude of 5 degrees.

![Fig. 7: Block diagram of PID controller.](image)

![Fig. 8: Left: Open loop tremor signal. Right: Simulation results of PID controller](image)

**3. Results and Discussion**

The paper presents a simulation of the arm tremor suppression via reciprocating movement of the anti-shaker. By using PID controller with \( K_p = -1.9, K_d = 0.08 \), and \( K_i = -10.9 \), the result of suppression is in great satisfactory.

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5. References


