DESIGN, FABRICATION, AND ANALYSIS OF TREMOR TEST RIG TO IMITATE HUMAN HAND TREMOR

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ABSTRACT

Parkinson's disease has no cure and the only treatment can be done is to relieve the symptoms. An anti-tremor device, which is a biomechanics approach, can be used to reduce hand tremor. Therefore, any device development should go through lab testing process before applying them on a human being. Here is where the test rig comes into picture as a device that can vibrate along the arm model, which is very similar to the human postural tremor behaviour. In this experimental work, a comparison between axial and rotational test rig where their frequencies are used for this analysis. Acceleration and angular velocity of a selected point on the hand model are captured and recorded. The input data for Parkinson's patients are used to vibrate the hand model. The output test rig data accuracy is verified by comparing with the frequency of the patients' hand tremors. From the result, the frequency of test rig and patients's hand tremors occurred at similar frequency of 4.813 Hz within their frequency range. This finding can assist future researchers in designing and fabricating a test rig or any device to suppress Parkinson's patient's postural tremor.

Keywords: *Parkinson, tremor suppression, biomechanical hand model, test-rig.*

1.0 INTRODUCTION

Parkinson's disease (PD) is a multi-symptomatic syndrome as almost all patients will experience tremor at any given time when the disorder possesses [1-3]. PD tremor is due to an abnormality in the central oscillator which causes reduced community ambulation and increases the danger of slips, falls, and faults [4]. Tremor is one of the most spread diseases amongst the population of patients diagnosed with movement illnesses. This is why medical scientists and engineers take tremors so seriously. It often involves the hands, which is then called hand tremors, but it can also be present in the head, mouth, voice or foot. Hand tremor affects millions of people worldwide.

Tremor is defined as an unintended, rhythmic muscle movement. According to [5] resting and postural tremor are two types of tremor that can always be seen in the Parkinson's (PD) patients. Resting tremor occurs within a frequency of 3-7 Hz when the muscles stay relax, and limbs are fully supported. While postural tremor appears within 5-12 Hz where a part of the body is maintained at a fixed position and may also persists during movement [6].

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However, by observing the statistical percentage of the PD patients, the researchers found out that 75% individuals suffer from rest PD tremor while 60% of them suffer from postural PD tremor [7].

To understand the measurement of involuntary hand motion is very crucial due to the fact that the data is used to emulate tremor on test rig. Also, it is to build the anti-tremor device for non-medical therapy development. There are many techniques to measure the acceleration, angle, and displacement of the involuntary hand gesture, such as accelerometer, gyroscope or even laser displacement sensor. Each technique has its own advantages and disadvantages [7-12]. The aim of this study is to develop an experimental rig which can simulate the behaviour of human postural hand tremor. This is carried out through identifying the suitable excitation frequencies which could represent the tremor behaviour.

2.0 DESIGN CONSIDERATION

The experimental process went through two stages: design and fabrication for the test rig and data collection. Test rig is designed to perform the experiment on hand-arm model in horizontal axis to emulate postural tremor before experimenting anything on Parkinson's patients. However, the test rig works to hold the hand-arm model where it can vibrate in Z-axis and rotational X-axis, in a movement that imitate patients's Parkinson hand tremors. The PD patients' postural type of tremor is selected for this study because the frequency range of postural tremor is greater compared to the resting tremor [7], [13]. For the second part, data is collected from Parkinson patients at Malaysian Parkinson Disease Association.

3.0 METHODOLOGY

3.1 Experimental Rig

The aim for this tremor test rig is to imitate the human hand tremor as precise as possible. As shown in Figure 1, a rotational motor was used to rotate in Z-axis and vibration exciter or shaker vibrated the artificial hand in X-axis. Thus, the performance of the tremor test rig was validated in terms of frequency domain with comparison to the data obtained from the actual hand tremor.

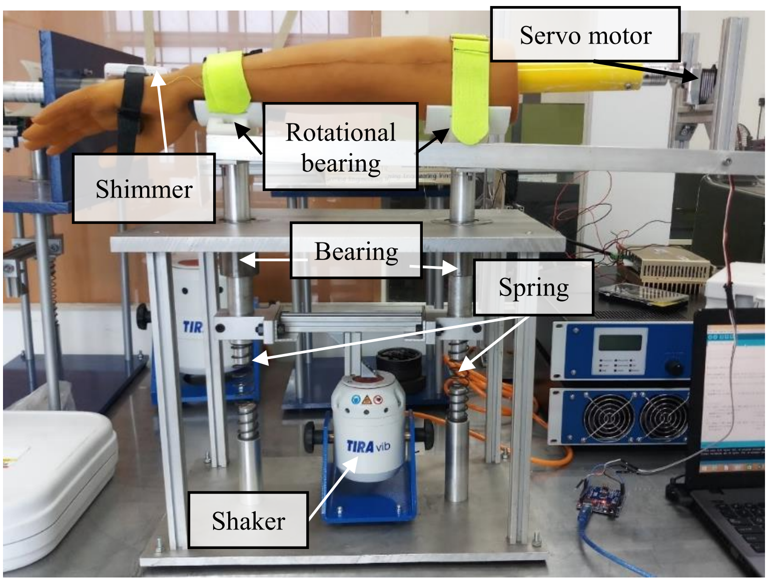


Figure 1: Hand model and experimental test rig

The main parts of the experimental test rig were servo motors, shaker, two springs, two rod bars, and two holders. To hold the upper rod bar firmly, the linear bearings were used to provide free motion in vertical direction with less friction.

Springs at the middle of the test rig which separated the upper shaft and lower shaft provide a good vertical vibration oscillation because it can elongate with tension load or shorten with compression load. Furthermore, the base of the test rig which holds the small vibration exciter rig uses the vibration mount in order to avoid the test rig from the external shake during testing. The external vibration surely can affect the accuracy of the result. This rig was designed so that the servo motor is permanently attached to it. In order to decrease the weight of the upper part of the test rig, the servo motor is attached straight to the aluminum bar without any frame.

The shaker was functioning so that it vibrated the hand in Z-axis. This test rig was equipped with sliding hand holder to support and ease the hand movement during the rotation of the servo motor. It was designed by using Polyoxymethylene (POM) material, which has very smooth surface and produces less friction. The hand holder was attached with an aluminum shaft. To gain a light weight and high strength to support the hand model, an aluminum plate was chosen as the main body for the test rig. The solid plate was used to ensure sufficient stability to the rig.

3.2 Experimental Setup and Data Capturing

Data was collected from The Malaysian Parkinson's Disease Association's PD patients, using the shimmer sensor as shown in Figure 2. The device comprises of accelerometer and gyroscope sensors in which it is capable of measuring linear and rotational movements in order to observe the behaviour of hand tremors clearly. The data collected was recorded in time domain series.

Figure 2: Shimmer device attached to hand model of test rig during testing

The benefits of using Shimmer device are: it is an intelligent wireless sensor which can record and transmit data to computer in real time. In addition to these, it is also very light in weight and it is a very comfortable and convenient sensor to be used on PD patients. The collected data was then applied on the test rig to simulate hand tremors. The linear data was injected to the shaker in the test rig so that it can vibrate in vertical direction Z-axis while the rotational data was then injected to servo motor that was placed at the end of the hand model. Prior to the running of the experiment, calibration of Shimmer and servo motor were done to confirm the accuracy of all data.

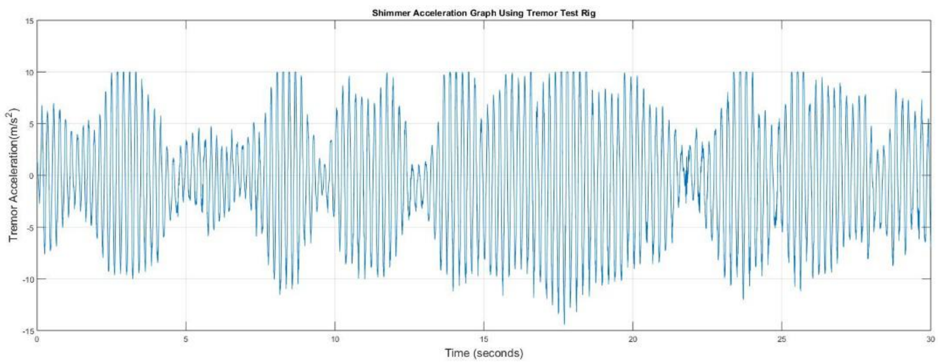
This experiment used sampling rate of 512 Hz. All input-output data went through Data Acquisition System (DAS) NI PCI-e 6363 and were recorded and displayed on the computer screen for further readings and analysation. LabVIEW is a software that was used to process all data and display it by using the software features. By using MATLAB software, the acceleration in time of the domain data is converted to frequency domain graph by using power spectral density (PSD).

4.0 RESULTS AND DISCUSSIONS

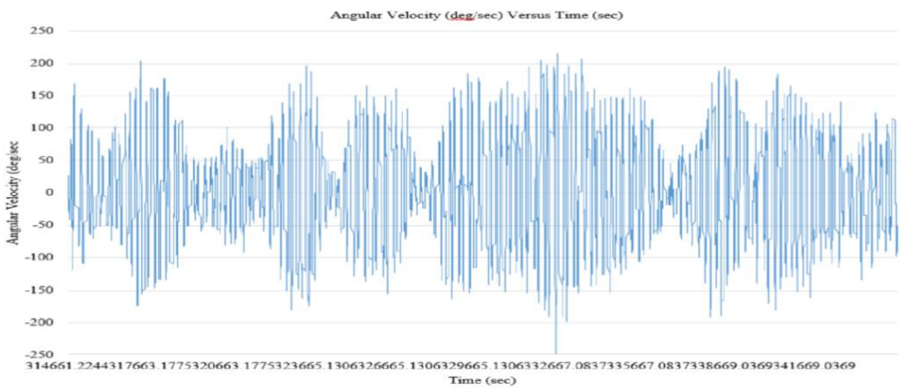
This study aims to investigate the capability of the test rig to mimic the Parkinson's patients' hand tremors. The test rig is designed to be in postural position, where the silicone hand is situated horizontally, similar to patients holding their hands at 90° to their upright bodies. Therefore, the test rig is validated using the frequency domain obtained from the test rig.

Figure 3(a) shows the acceleration versus time for postural tremor. It fluctuates between -14.9 m/s^2 and 10 m/s^2. From the graph, the acceleration signal clearly shows rhythmic movement. Figure 3(b) depicts the graph for angular velocity for the postural tremor. It ranged between -250 deg/s and 210 deg/s, which indicates that the rotation movement is quite high and is obvious. Figure 3(c) illustrates the power spectral density (PSD) graph, which gives a result of 4.813 Hz in Z-axis.

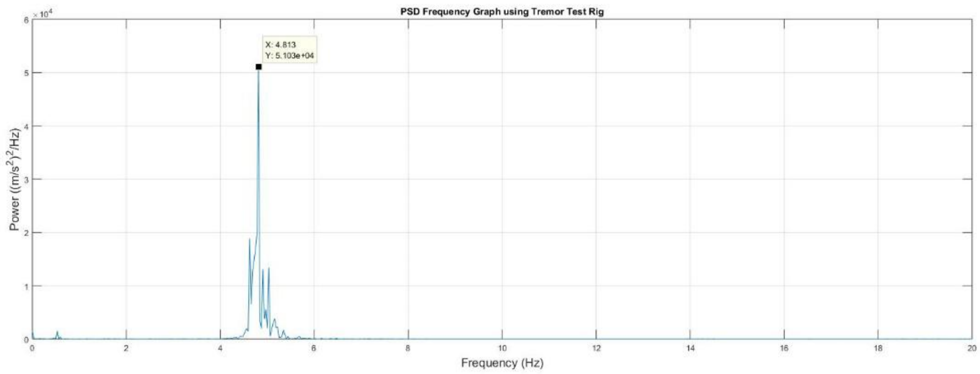
It was observed that the angular velocity reading is too high due to the fact that the slow response of servo motor to track the tremor position during rotational movement testing. Nonetheless, it is still acceptable because the frequency obtained was at 4.813 Hz, which is close to the postural Parkinson frequency that range from 5 to 12 Hz [6]. Thus, the objective of this experiment was achieved.



(a)



(b)



(c)

Figure 3 a) Time domain signal for acceleration behaviour; b) Time domain signal for angular velocity behavior, and c) Frequency domain.

5.0 CONCLUSIONS

Based on the results obtained, the aims of developing the test rig were achieved. As it was mentioned earlier, the tremor test rig is a system that can vibrate the hand model in Z-axis and rotate in X-axis rotational motion, which is expected to mimic the likeness of the Parkinson patients' hand tremors. The test rig was capable of imitating the acceleration data in Z-axis and was collected from the PD patients and it vibrates at a frequency, which was close to patients' tremors in postural conditions. As stated earlier, the test rig is designed and fabricated to assist the researchers to develop tremor suppression device where it can be tested on this test rig instead of on the patients' hands. Hence, this test rig helps save the researchers' time as well as not giving any kind of discomfort to patients during and when doing the experiment. In addition, it can prevent unwanted frequencies that could come from random vibration discomfort in PD. In conclusion, the test rig can portray the behaviour of human postural tremors.

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