Development of Hand-arm Model Rig for Tremor Excitation

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Abstract

This paper describes the development of a hand-arm model rig to simulate human tremor behaviour. The experimental rig is designed as an apparatus to induce vibration along a hand-arm model. An Intra Vernacular (IV) Training arm is used as the hand-arm model. Displacement and acceleration behaviour at three selected points along the hand-arm model were recorded by mean of piezoelectric accelerometer. The data from the experiment can be used for further analysis of the human hand-arm tremor especially for Parkinson's disease (PD) patients. Results from the experiments are raw data which can later be used in designing an appropriate instrument that can suppress the hand tremor.

1. Introduction

Tremor is an unintentional, rhythmic muscle movement which reduces the ability to perform desired task. The tremor is primarily a single frequency phenomena. It ranges between 4 to 12 Hz and can effect various parts of the body [1], [2]. Tremor investigations mainly focus on the modeling of the tremors in order to distinguish different causes of tremor patients [3]. The most commonly tremor occur at the hand. It restricts movement of the tremor patient especially in holding and writing. In tremor investigation, the acceleration of tremor movement is often measured with accelerometer and processed as random time series [1], [4], [5], [6].

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 [4]. Two types of tremor always seen on the Parkinson's (PD) patients are resting tremor and postural tremor. Resting tremor occurs when muscle stay relaxes and limbs are fully supported, such as when the hands are stay on the lap. Postural tremor appears when a part of the body is maintained in a fixed position and may also persist during movement [7].

Resting tremor occurs within the frequency range 3-7 Hz, occurs in up to 75% of individuals with PD [4]. Postural tremor is typically observed between 5 and 12 Hz and is symptomatic in around 60% of PD patients [4]. The dynamics responses of the hand and arm must have a great influence on the injury potential of hand-transmitted vibration [5]. It has not yet been discovered which characteristics of the vibration are responsible for detrimental effects [5]. The absorption of vibration energy in the human hand and arm has been claimed to correlate better with vibration injuries than the currently used measurements of the acceleration [5].

2. Design Consideration

Human hand-arm can be model as a three degree of freedoms 3-DOF's system [8]. The experimental rig was formulated for the purpose of experimental data collection at hand-arm model before an actual experiment of the human hand tremor. The rig is designed to hold the hand-arm model and provide vibration at two separate locations (wrist and upper arm).

In this study, the rig has been designed to support the hand-arm model in horizontal axis to emulate postural tremor condition. The PD patients' postural type of tremor was selected to be studied because the frequency range of postural tremor is greater compared to the resting tremor [4]. By engaging unbalance mass to a DC motor, vibration is induced onto the hand-arm model, hence, providing postural tremor behaviour. This rig is usable for research especially in suppressing the postural tremor by measuring the tremor movement and developing the appropriate instrument such as piezoelectric actuator

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[2] or anti-vibration gloves to compensate the tremor [9].

3. Methodology

3.1 Experimental Rig

Figure 1 shows the developed hand arm model rig. The experimental rig is equipped with two DC motors, two springs and two hand holders. Material used for the rig is aluminium as it is easy to fabricate, light and tough. Unbalance masses were attached at the motors and act as vibration exciter. The purpose of having the spring in the middle between the upper and lower rod bar is to separate the rod bar and provide vibration effect while the motor rotates the unbalancing mass. It will allow the upper bar to vibrate freely with regards to the speed of the motor. The upper bar will have a higher vibration as the motor speed increases. The hand-arm model is placed horizontal on the hand holders of the rig such that the model hand-arm vibration resembles hand postural tremor. In the experiment, the model of Intra Vernacular (IV) Training arm was used as a model hand-arm.

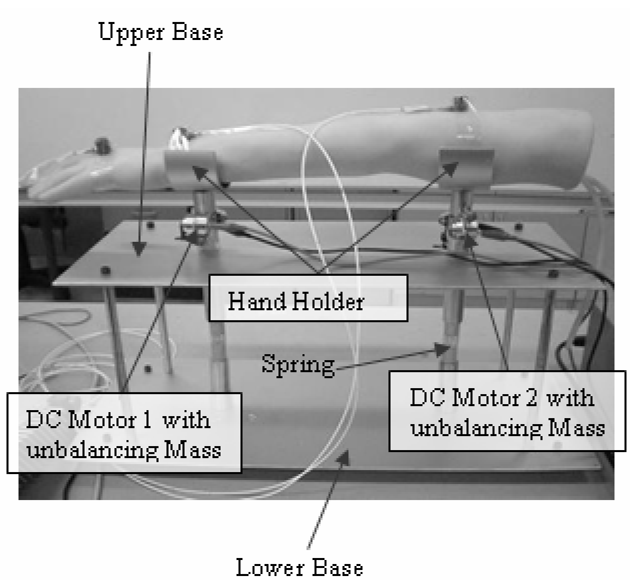

Figure 1. Hand-arm model rig

3.2. Experimental Setup and Data Capturing

The experimental set-up used in the study is illustrated in Figure 2. The model hand-arm is measured with Kristle Type 8630C50 uniaxial accelerometer (range $\pm$ 50g). Prior to the experiment, the accelerometers were calibrated using the calibrator as shown in Figure 3 at the frequency of 160 Hz. Acceleration due to gravity was assumed to be 9.81 ms^{-2}. Three accelerometers were used and attached at three selected points. The vibration signals were then fed into a data acquisition fitted in PAK MK II analyzer from Müller-BBM VibroAkustik Systeme. PAK provides in-field reliability together with high signal sensitivity and execute more than 100 input-channel measurements with simultaneous time-signal recording and real-time analysis [10].

The accelerometer (tremor) data measured with linear frequency weighting at the time constant fast/.125s and at cutoff frequency 30Hz. The data were transferred to a HP Pavilion dv1000 laptop computer via a standard 10/100Mb LAN interface and connect to PAK MK II analyzer. PAK Mobile MK II software version 5.3 was used process the data and to provide the acceleration and displacement analysis in both time and frequency domain [10]. PAK Mobile MK II can display acceleration and displacement analyses with simultaneous measurements and it also provide a user-friendly interface [10]. Displacement data were obtained by double integration of the acceleration data using the built-in integration function of the software.

The vibration of model hand-arm is sampled at the rate 512 Hz for 32 seconds for one test cycle and at each location. A different voltage was supplied to the DC motors that rotate the unbalance mass of the wrist and the upper arm. For the experiment, 6 volts were supplied to the wrist and 2 volts were supplied to the upper arm. This is to provide a larger vibration at the end of the hand-arm to emulate the actual behaviour of hand tremor.

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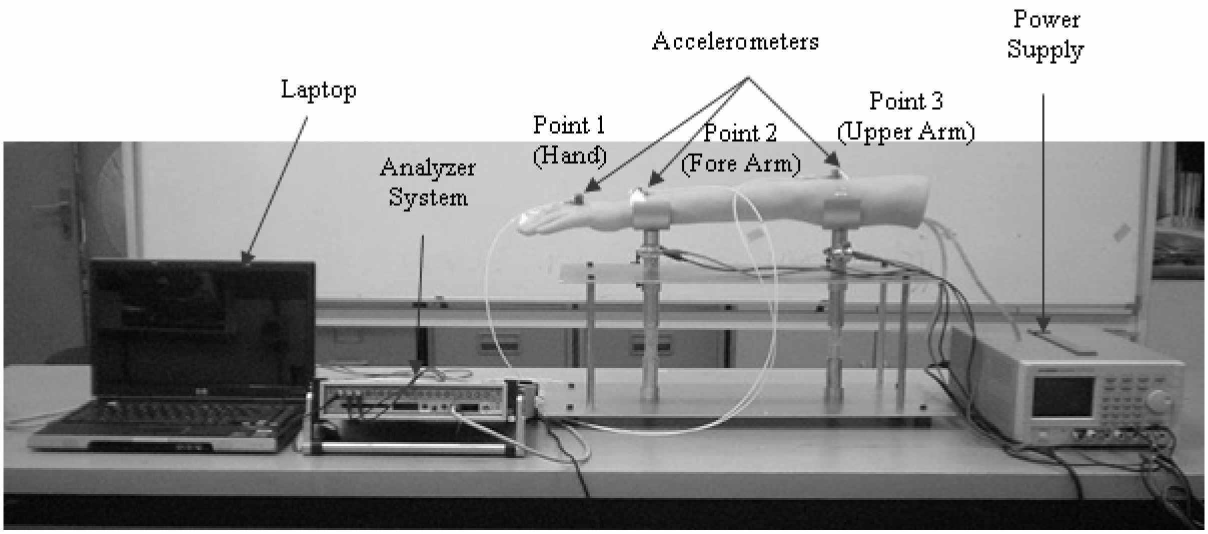

Figure 2. The experimental setup

Figure 3. Calibrator Kristle Type 8921

3. Results and Discussions

In the test, only the hand motion in vertical plane is observed. The proposed of the study is to gain knowledge of acceleration and displacement behaviour at three selected points along the hand-arm model. The chosen points are at the three hand portions which are the hand, fore arm and upper arm. The response characteristics due to vibration excitation at each location were obtained.

The acceleration and displacement response for all locations are illustrated in Figure 4 and Figure 5. From Figure 4, the acceleration response results in time domain does not show much difference between the hand, fore arm and the upper arm.

The accelerations are in the range of between 0.45 m/s^2 to 0.54 m/s^2 throughout the 32 seconds excitation. The frequency response result for all locations does not show any distinct difference with the maximum acceleration observed to be around 14.62Hz. The maximum acceleration amplitude for hand, fore arm and the upper arm are 0.000674 m/s^2, 0.000554 m/s^2 and 0.002462 m/s^2 respectively. It shows that the acceleration response is higher at the hand followed by fore arm and upper arm.

The displacement data acquired shows similarity in its time response (see Figure 5) with the displacement ranges between -5.5×10^{-6}m and 5.2×10^{-6}m throughout the 32 seconds excitation. Meanwhile, displacement frequency response shows that highest amplitude can be observed at a frequency of 14.62 Hz for all locations. The highest displacement occurred at the hand (8.0×10^{-8}m) and thereafter at the fore arm (6.6×10^{-8}m) and at the upper arm (2.9×10^{-7}m).

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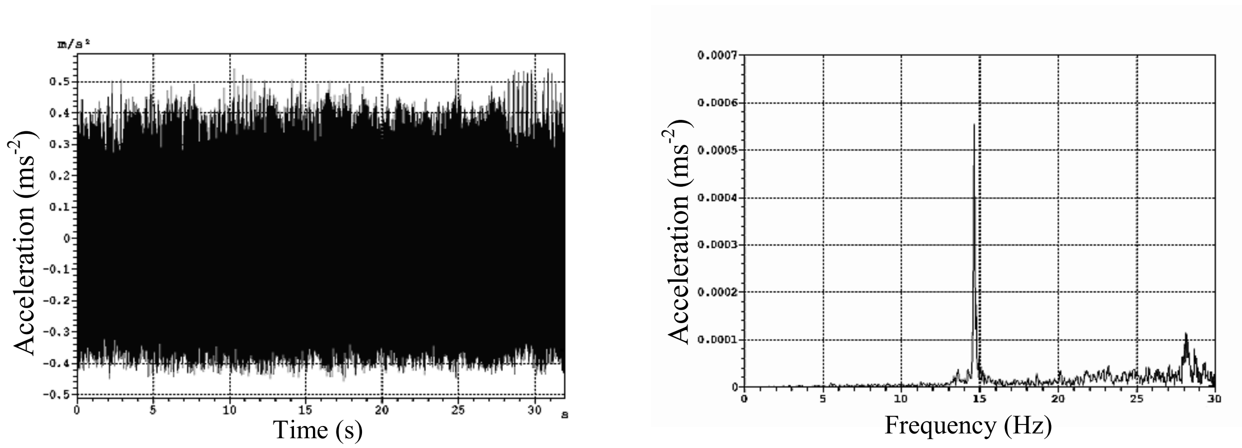
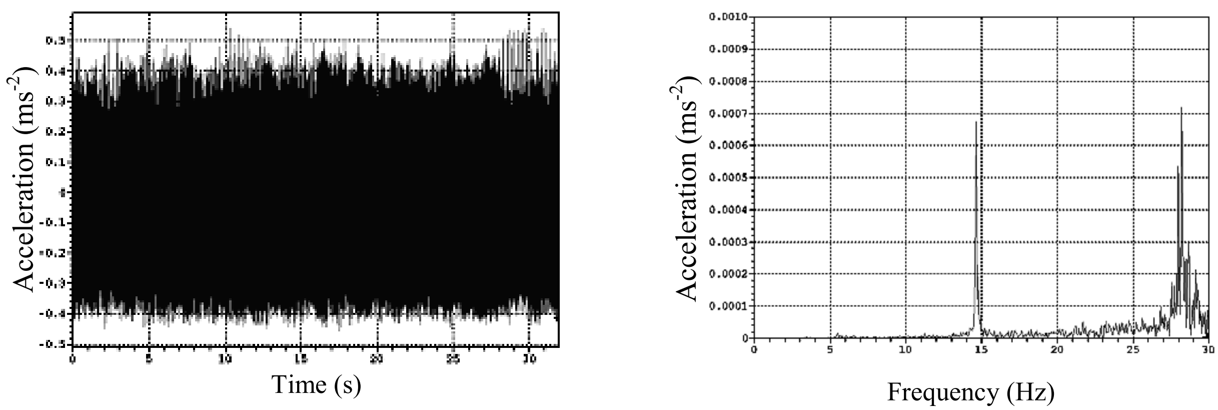


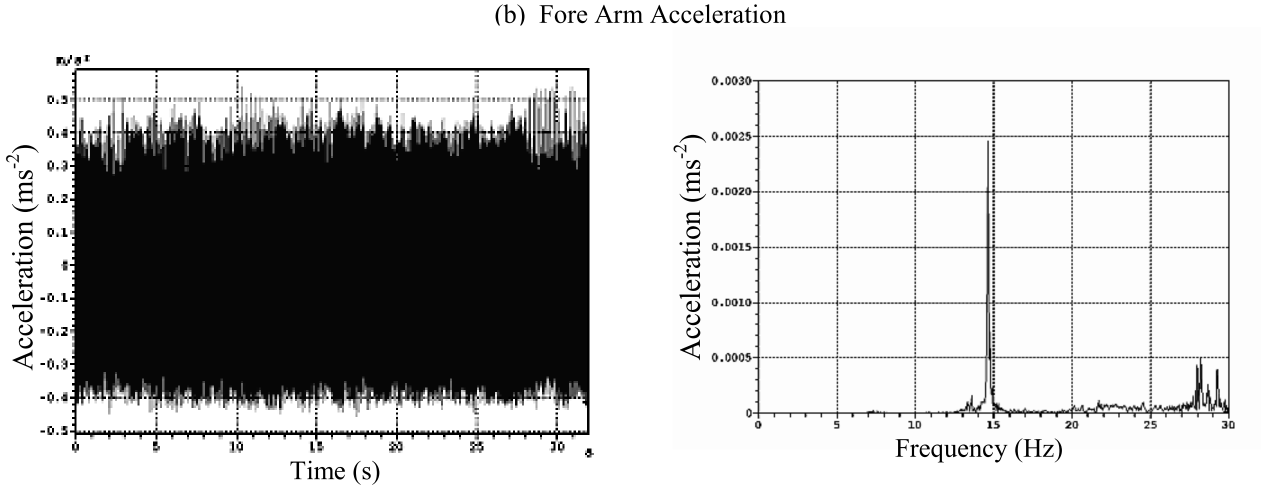
Time domain Frequency domain

(a) Hand Acceleration



Time domain Frequency domain

(b) Fore Arm Acceleration



Time domain Frequency domain

(c) Upper Arm Acceleration

Figure 4. Response of the acceleration of model hand-arm.

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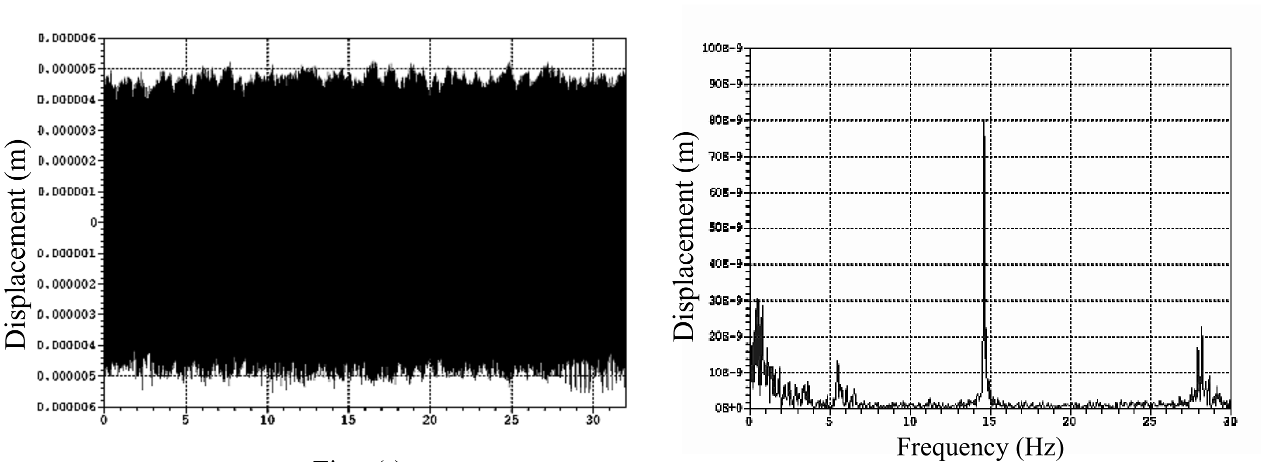
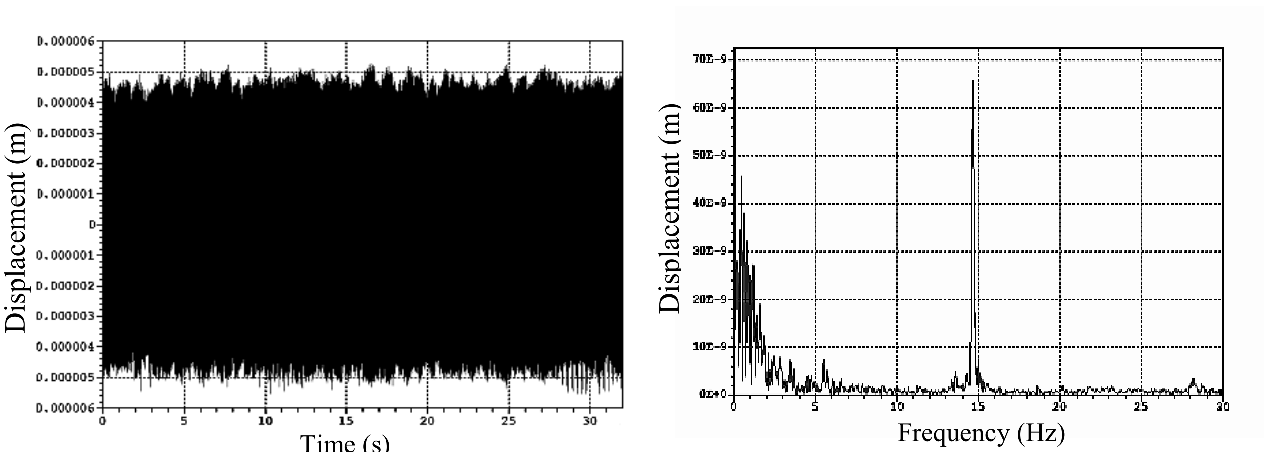


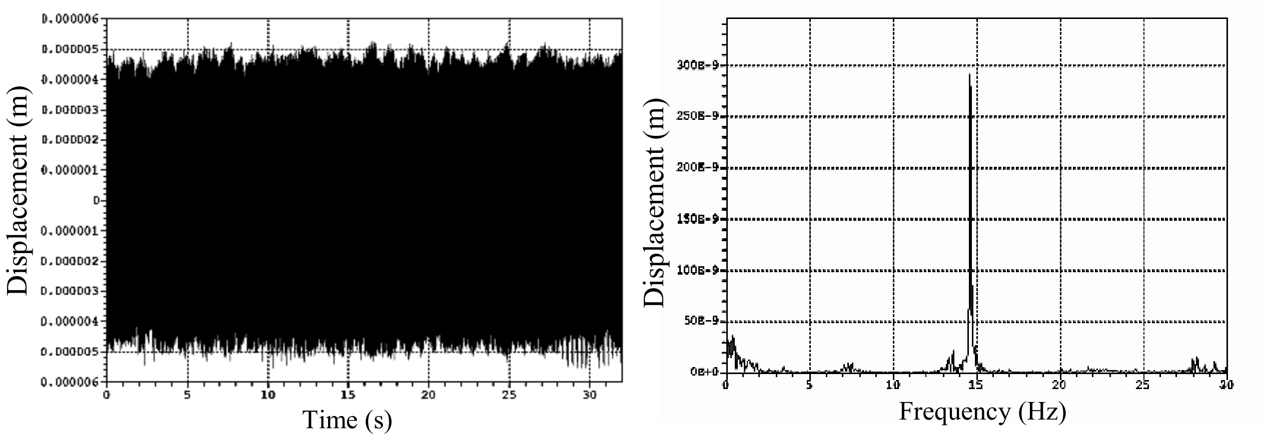
Time domain Frequency domain

(a) Hand Displacement



Time domain Frequency domain

(b) Fore Arm Displacement



Time domain Frequency domain

(c) Upper Arm Displacement

Figure 5. Response of the displacement of model hand-arm.

4. Conclusions

The model of hand and arm subject to vibration has been investigated in terms of acceleration and displacement responses. From the experimental results, it can be concluded that there is not much difference in acceleration and displacement behaviour in the time domain. However, high acceleration and displacement responses are generated at the frequency of 14.62 Hz. This study will be a great aid to the investigation of future tremor collecting data for hand tremor of Parkinson's (PD) patients.

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