Measurement and Behaviour Classification of Tremor Patients

A. Cheraghizanjani, A. As'arry, Z. M. Yusop, M. Z. Md. Zain, M. Hussein

***Abstract*—**This study is intended to assist neurologist in measuring and identifying the level and range of tremor in some patients who suffer neurological diseases. Prior to quantifying, a tremor test rig was designed and fabricated. Two laser displacement sensors are used to quantify tremor behavior at hand in X (horizontal) and Y (vertical) directions. In this paper, two types of tremor condition which are postural and rest tremor were investigated and discussed. The appropriate programming is used to analyze, classify and show range and type of the disease.

***Keywords*—**Postural Tremor, Rest Tremor.

I. Introduction

Movement disorder diseases can disturb a patient's life. One of the most common is Parkinson. Patients will face problems in picking up and holding objects because of tremor or vibration of hands which are the most obvious and important symptoms of tremor diseases [1]. Tremor is an abnormal repetitive shaking movement of the body which is unintentional, rhythmic and roughly sinusoidal [2]. Muscle shaking may involve any limbs (even the head or voice), but it is often obvious in the hands [3]. Elimination or at least reduction of this tremor is the final goal of any research in this area. In order to achieve this, relevant data on the diseases and types of diseases should be obtained. The main features of each tremor are frequency and amplitude. Tremor frequency is mostly dependant on the pathophysiological mechanism and is fairly stable over time [4]. There are three main positions to measure hand tremor (include: resting, postural and action position). Each disease is recognizable at specific position [5]. Rest tremor occurs when the affected body part is completely supported against gravity (e.g., hands resting on the lap) [6]. Postural tremor occurs when the affected body part maintains position against gravity (e.g., extending arms in front of body) [7]. Action tremors are produced by voluntary muscle contraction (e.g, during movement of the affected body part from one point to another) [8]. There are three main approaches to measure the hand tremor including; 1) acceleration transducer 2) velocity transducer, and 3) displacement transducer. Besides that, other type measurement method is using digital or graphical tablets in 2D surface and camera system to investigate hand motion trajectory in 3D coordinate [9], [10]. But, most researchers prefer to use accelerometer as a sensor for measuring hand tremor. This probably due to the low cost of the sensor, easy to obtain velocity and displacement data by single or double integration of acceleration signal or easy to implement due to the light weight and small size of the transducer [11]. Even the displacement signal simply obtains from double integration of acceleration signal. However, the result is not satisfied due to the amplified noise from the first and second level of integration process [12]. In addition, for every integration part need to apply filter and required time and effort to tune filter's parameter to get realistic output.

Due to the advanced technology in sensor application, the amplitude of tremor behavior data can be precisely quantified by using laser displacement sensor. The device performs non-contact single-point to the target surfaces and precisely measure vibration system corresponds to alteration of the diffraction ray of the laser [13]. Thus, the outcome display signal becomes more visible and realistic. There were some researchers employ laser displacement sensors to measure human hand tremor [14] – [16]. Most of them interest to investigate tremor in the vertical plane (Y-axis).

Therefore, the objective of this study is to quantify human hand tremor in X (horizontal plane) and Y axes. To do that, two laser displacement sensor were employed at the tremor test rig. Tremor will be measured and recorded in real time data using LabVIEW software package. The time data will automatically transform to frequency data by using spectral measurement block. Thus, the findings of this study will display in time and frequency domain. The tremor classification based on frequency coherence peak.

The patient will be tested in two conditions which are resting and postural conditions. After that, both conditions

Manuscript received June 27, 2011: Revised version received June 27, 2011.

A. Cheraghizanjani is with the Department of System Dynamics & Control, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Johor, Malysia phone: +607-533-5948; fax: +607-553-5199; e-mail: alireza.cheraghi7@gmail.com.

A. As'arry is with the Department of System Dynamics & Control, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Johor, Malysia

Z. M. Yusop is with the Department of System Dynamics & Control, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Johor, Malysia

M. Z. Md. Zarhamdy is with the Department of System Dynamics & Control, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Johor, Malysia phone: +607-533-5948; fax: +607-553-5199; e-mail: zarhamdy@fkm.utm.my.

M. Hussein is with the Department of System Dynamics & Control, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Johor, Malysia

will be classified to five ranges which are Holmes, Parkinson, Neuropathic, Low Essential and High Essential. This study includes two main parts which are 1) hardware 2) software, in which the outputs of hardware are the inputs of software. Overall, this study intended to assist neurologist in measuring and identifying the level and range of tremor in patients who suffer neurological diseases (this study covers only the hand tremor). The proposed classification provides a fast identification of the type and level of the disease.

II. Device Designing

As shown in Figure 1, an appropriate tremor test rig device is designed to measure the hand tremor and obtain the data. Coherence device is switchable between the two main conditions (resting and postural). The holder part (Figure 1) is adjustable to allow change of the position of measurement. Figure 2 shows the view of test rig in resting condition. Laser displacement sensors are installed on the hollow cylinder. One is installed along the X-axis and the other is along Y-axis. A hand part (Figure 3) is used to provide a suitable reflection beam from the sensors. The light spot of this instrument should be approximately adjusted to the center of the target that is attached on the basic plate to stay in range. In postural condition, patient extends the forearm on the supporter after inserting the hand into the cylinder, while in resting condition, patient stands next to the table and places the hand through the cylinder. All data are collected using coherence data acquisition card to be transfered to software. Figure 4 shows the hardware and software configuration of the experimental rig.

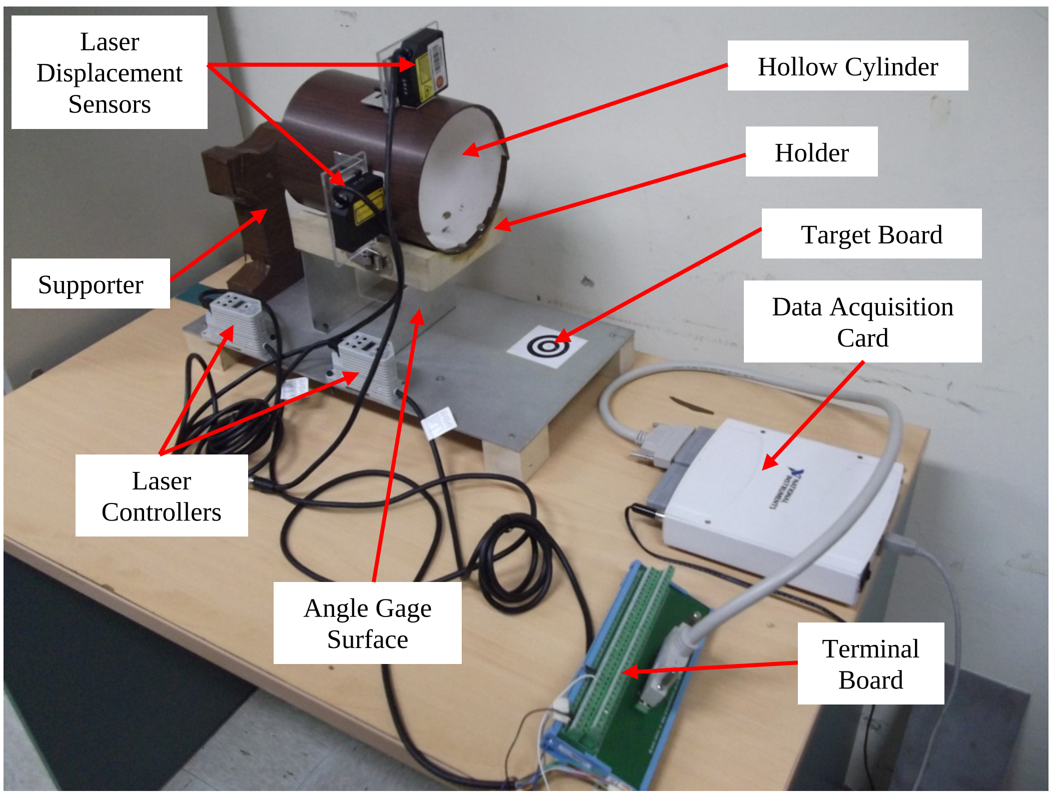

Fig.1: Measurement device in a postural condition.

Fig. 2: Measurement device in a resting condition.

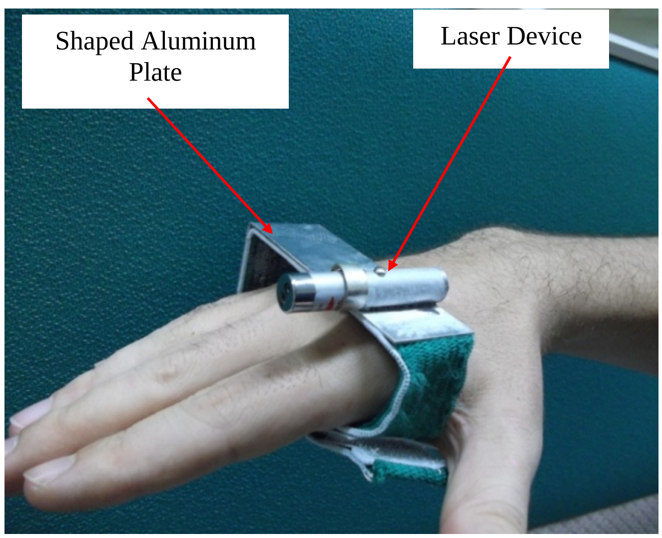

Fig. 3: Hand part

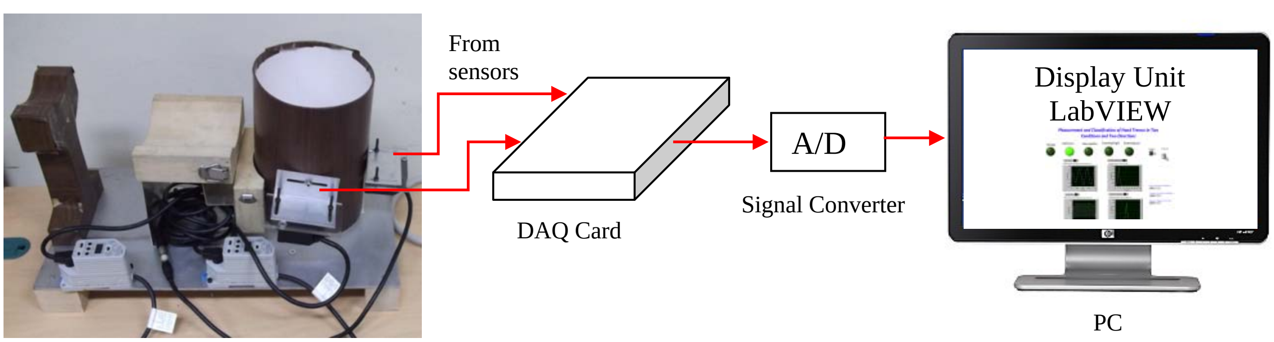

Fig. 4: Hardware and software configuration of the experimental rig

III. Data Processing

A. Laser Displacement Sensor Calibration

Prior to the measurement, the laser displacement sensor is calibrated to confirm the transfer function from its data sheet. The transfer function which relates the output voltage signal (obtained from the laser sensor) to the displacement (mm) unit can be easily obtained by multiplying the voltage signal to its sensitivity (see Equation 1). The calibration unit can be confirmed by measuring at least two points having a known distance between them [15]. In this calibration test, three points were selected at 0 mm, 6 mm and 10 mm. From laser displacement sensor data sheet [17], the value for sensitivity is 0.5 V/mm. Figure 5 shows the calibration chart for the laser displacement sensor.

$$\text{Voltage (V)} = \text{Sensitivity} \times \text{Displacement (mm)} \qquad (1)$$

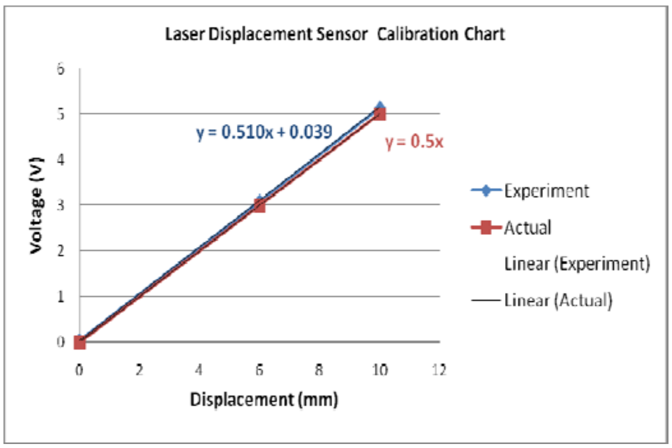

Fig. 5: Calibration chart for laser displacement sensor

B. Superposition

For the purpose of superposition of vertical wave (along X axis) and horizontal wave (along Y axis), it is required to calculate the peak frequency for each direction and then apply the formula to obtain the frequency of final orbital motion on the surface. For the purpose of calculating the frequency of each signal, spectral measurements is used where the input is filtered signal and the output is frequency spectrum. Frequency peak is obtained from this output. Output of frequency estimated is a number which states the frequency peak of tremor. The procedure was then repeated for the other direction. The two different numbers serve as input to the equation.

The final step of obtaining orbital motion frequency includes the superposition Equation 2 which shows the frequency of orbital motion. This number is input of the classification.

$$F_{orbital} = \sqrt{F_x^{\,2} + F_y^{\,2}} \qquad (2).$$

C. Classification

For the purpose of classification of hand tremor and recognizing of disease type, it is required to define some ranges and intervals (Table 1). Each type of hand tremor disease occurs in one specific range (frequency interval) and is more obvious in one specific condition (resting or postural).

Table 1: Classification of tremor diseases according to frequency ranges and conditions [18].

Tremor type	**Condition**	**Frequency range**
Holmes	resting	2-4 Hz
Parkinson	resting	4-10 Hz
Neuropathic	postural	4-6 Hz
Low Essential	postural	6-10 Hz
High Essential	postural	10-12 Hz

Hardware part supports both conditions. To match the software part with both conditions, a relay is used which operates as a key to switch between the resting and postural condition. These switches are observable on the control panel and the user is able to turn on/off for each condition. If resting condition is on, the hardware part is in the resting position and postural switch must be off.

IV. Results and Discussions

Actual results are represented in this section and all evaluations are obtained with the presence of the patient. Practical measurements are done on one patient in two different conditions. Some of the considered tremor diseases have the same interval frequency but in different condition (for instance, Essential tremor and Parkinson). This device would recognize both diseases in both conditions with the same intervals. Physician is able to recognize the exact disease between only the two options with any other medical symptoms.

This program is using the “while” loop and according to the design method, the program is active while recognizing the hand tremor disease. As shown in Figure 7, after stoppage of program, all results (include: displacement diagram along X axis, displacement diagram along Y axis, frequency graph along X axis, frequency diagram along Y axis, peak frequency along X axis, peak frequency along Y axis, peak frequency on XY, patient’s disease) are provided on control panel. There are also two switches on the control panel (Figure 7) for the user to choose the condition before measurement by turning on/off these keys.

A. Resting Condition

To measure the hand tremor in resting condition, two points should be checked. First is the condition of the device where cylinder should be vertically adjusted with respect to the ground and should be contact precisely to the angle gage surface. Second is coherence keys which are on the control panel of the software ,which for this condition, resting key should be on (upward) and postural key should be off (downward). As shown in Figure 6, patient should place his/her hand into the measurement space.

The results are clear in Figure 7 which is represented on the control panel after automatic stoppage of the program. Displacement graphs of each direction are shown in the time domain. Investigation of tremor and recognizing the type of disease took 1 second. Amplitude displacement changed between -1.2 mm and 1.6 mm along X axis, and changed between -2.3 mm and 2.2 mm along Y axis. Frequency graphs are depicted on the control panel but peak frequency is critical and significant in this project which is 6.9Hz along X axis and its magnitude is $0.08m^2/Hz$. Peak frequency occurred at 7.00 Hz approximately, and its magnitude is $0.13m^2/Hz$. Numerical value of peak frequency is observable in each direction on the control panel. Final oscillation frequency is clear on the third row of numerical values which is 9.84 Hz approximately. According to the classification part, this specific frequency is the symptom of Parkinson in this condition.

B. Postural Condition

To commence the measurement in postural condition, two points should be checked. First is the condition of the device which should be horizontally adjusted with respect to the ground and relevant latch should be fastened to fix it. Second is coherence keys which are on the control panel of the software, the postural key should be on (upward) in postural condition and resting key should be off (downward). As shown in Figure 8, patient should place his/her hand into the measurement space.

Obtained results are displayed in Figure 9 which represents the control panel after automatic stoppage of the program. Displacement graphs of each direction are shown in time domain. Investigation of tremor and recognizing the type of disease took 1 second. Amplitude displacement changed between -0.4mm and 1.4mm along X axis and changed between -2.2mm and 1.3mm along Y axis. Frequency graphs are depicted on the control panel, but the peak frequency is critical and significant in this project which is 6.34Hz along X axis and its magnitude is $0.068m^2/Hz$. Peak frequency occurred at 6.40Hz approximately, and its magnitude is $0.36m^2/Hz$. Numerical value of peak frequency is observable in each direction on the control panel. Final oscillation frequency is clear on the third row of numerical values which is 9.00Hz. According to the classification, this specific frequency is the symptom of “essential tremor” (low) in this condition.

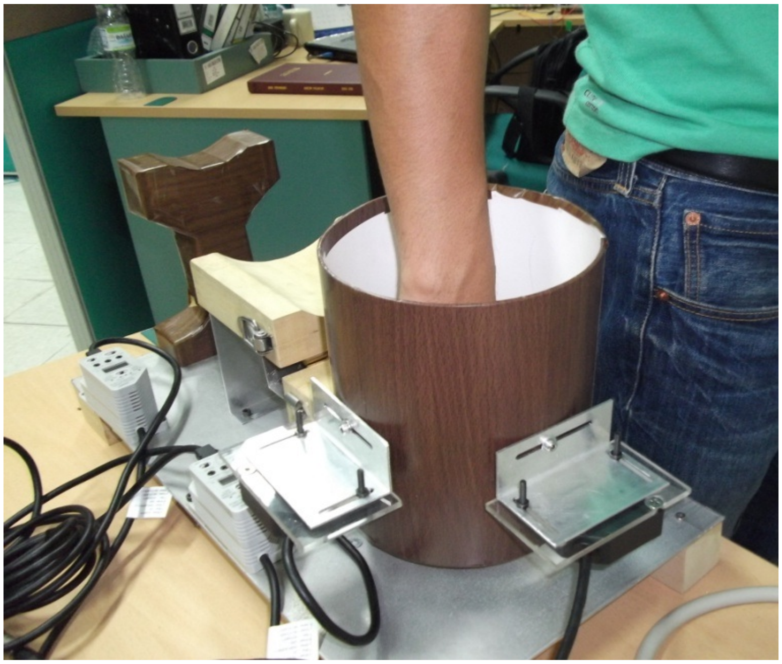

Figure 6: Measurement in rest condition

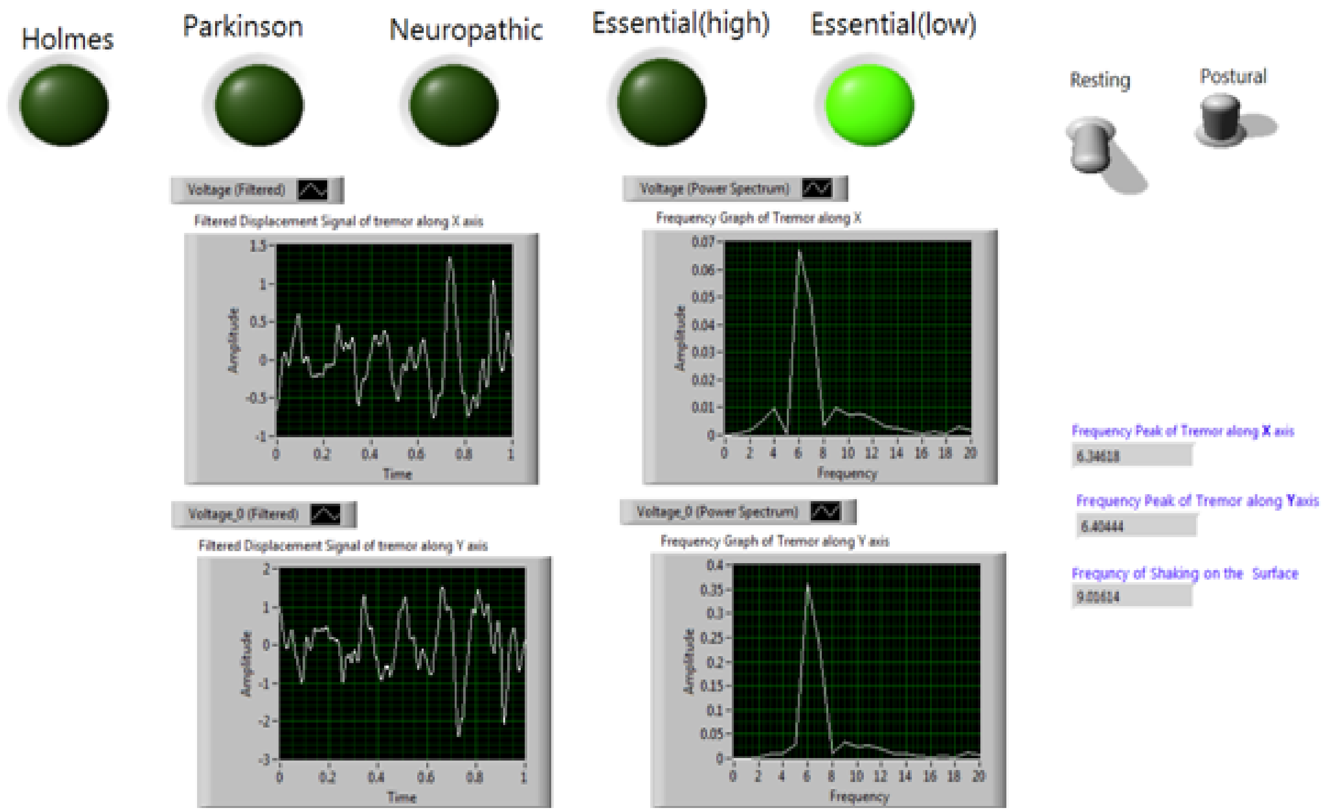

Figure 7: Control panel in postural condition

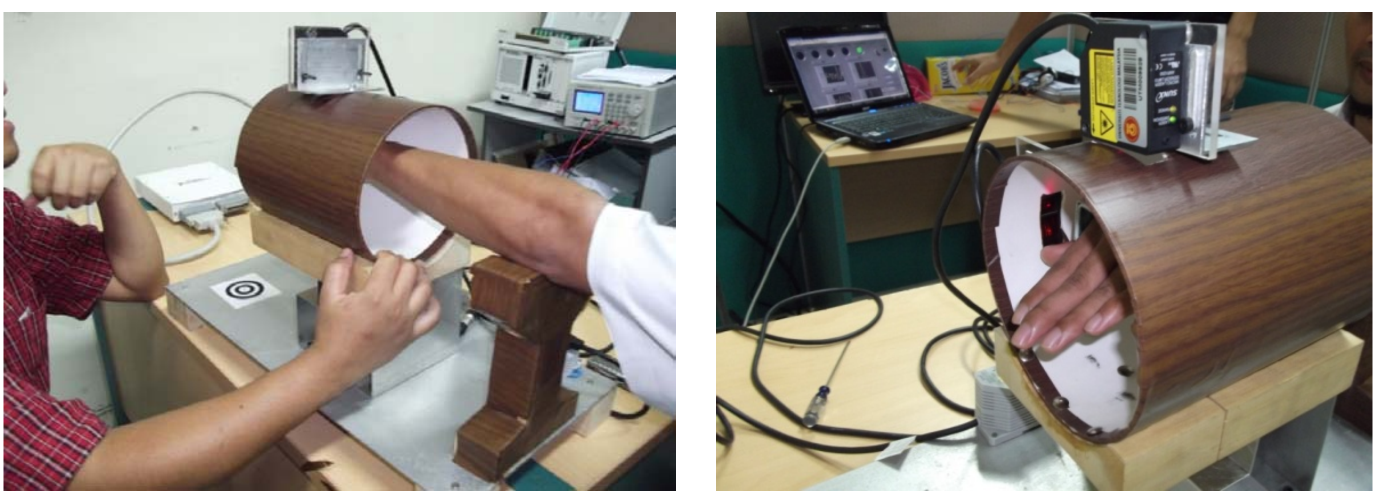

Figure 8: Measurement in postural condition

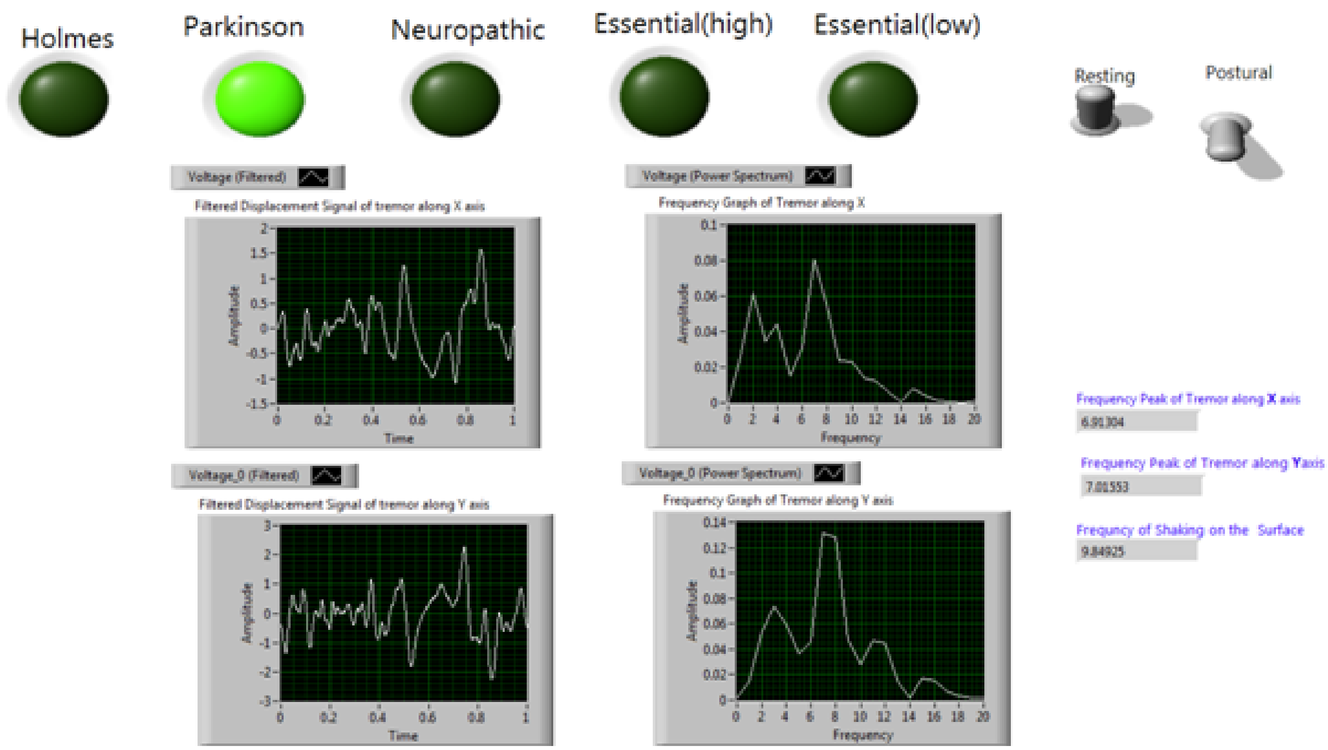

Figure 9: Control panel in resting condition

V. Conclusion

To measure the hand tremor, this study uses two displacement transducers; both of them are laser displacement sensors. The major parameter is amplitude of displacement of hand tremor's oscillation in this project that has been measured and recorded in the time and frequency domain. And our classification is according to frequency range. This study focuses on measurement of tremor hand at both conditions which include resting and postural condition in two axes (X, Y) because the tremor amplitude is most significant at these axes. There are two important conditions for measuring the hand tremor (resting and postural) because some of diseases appear only in single condition. This system is able to cover two conditions with changing of one part of that. Considered device experimentally is fabricated and is tested with human hand.

Acknowledgment

The authors would like to thank the Malaysian Ministry of Science, Technology and Innovation (MOSTI) and Universiti Teknologi Malaysia (UTM) for their continuous support in the research work. This work was financial supported in part by the Malaysia FRGS Fund under Grant number Vot. 78510.

References

[1] P. McNamara, R. Durso, and E. Harris. Life Goals of Patients with Parkinson's disease: a pilot study on correlation mood and cognitive functions. *Clinical Rehabilitation*, Vol. 20, 2006, pp. 818-826

[2] S. Kazi, A. As'Arry, M. Z. Md. Zain, M. Mailah, M. Hussein, Experimental Implementation of Smart Glove Incorporating Piezoelectric Actuator for Hand Tremor Control, WSEAS TRANSACTIONS on SYSTEMS and CONTROL, Vol 5, Issue 6, June 2010, 443 – 453.

[3] http://ezinearticles.com/?Hand-Tremor---Causes-and-Symptoms-of-Hand-Tremor&id=1105959

[4] B. Hellwig, P. Mund, B. Schelter, B. Guschlbauer, J. Timmer, and C. H. Lucking. A longitudinal study of tremor frequencies in Parkinson's disease and essential tremor, *Clinical Neurophysiology*. 2008

[5] S. M. D. Smaga. Tremor. *American Family Physician*, Vol. 68, No. 8, 2003, pp. 1545-1552

[6] Morrison, S., Kerr, G. and Silburn, P. (2008). Bilateral tremor relations in Parkinson's disease: Effects of mechanical coupling and medication. Parkinsonism and Related Disorder, Vol 14, pp. 298-308.

[7] S. Morrison, K. M. Newell. Postural and Resting Tremor in the Upper Limb, Clinical Neurophysiology, Vol 111, 2000, pp. 651-663

[8] Charles PD, Esper GJ, Davis TL, Maciunas RJ, Robertson D. Classification of Tremor and Update on Treatment, American Family Physician, Vol 59, Issues 6, 1999, pp. 1565-1572

[9] A. Izworski, M. Michalek, R. Tadeusiewicz, M. Rudzinska, J. Bulka, I. Wochlik, Acquisition and Interpretation of Upper Limbs Tremor Signal in Parkinsonian Disease, Proceedings of the 4th WSEAS International Conference on ELECTRONICS, SIGNAL PROCESSING and CONTROL, Rio de Janeiro, Brazil, April 25-27, 2005.

[10] Szabo Z., Storkova B., Hozman J., Zanchi V., Objective Assessment of Patients with Parkinson's Disease, 3rd WSEAS International Conference on REMOTE SENSING, Venice, Italy, November 21-23, 2007, pp. 39-42.

[11] M. Z. Md. Zain, A. As'arry, S. Kazi, M. Mailah, M. Hussein, M. Y. Abdullah (2010), Development of Experimental-rig for Human Postural Tremor Behavior, International Journal of Human Factors Modelling and Simulation, Volume 1, Number 3, November 2010 , pp. 339-351.
[12] K. E. Norman, R. Edwards, A. Beutter, The Measurement of Tremor using a Velocity Transducer : Comparison to Simultaneous Recordings using Transducers of Displacement, Acceleration and Muscle Activity, Journal of Neuroscience Methoids, Vol 92, 1999, pp. 41-54.
[13] R. Munteanu Jr., D. Iudean, M. Munteanu, R. Moga, M. Trusca, V. Dorca, High-Precision Measurements of Very Small Displacements Using the Laser Vibration Meter, 9th WSEAS International Conference on AUTOMATION and INFORMATION (ICAI'08), Bucharest, Romania, June 24-26, 2008
[14] B. Pellegrini, L. Faes, G. Nollo and F. Schena, Quantifying the Contribution of Arm Postural Tremor to the outcome of goaldirected pointing task by displacement measures. Journal of Neuroscience Methods, 139(2), 2004, pp. 185-193.
[15] C. Duval, Rest and Postural Tremors in Patients with Parkinson's disease. Journal of Brain Researcjh Bulletin., 70, 2006, pp. 44-48
[16] R. P. Meshack, K. E. Norman. A Randomized Controlled Trial of the Effects of Weights on Amplitude and Frequency of Postural Hand Tremor in people with Parkinson's disease. Clinical Rehabilitation, Vol. 16, Issue 5, 2002, pp.481-492
[17] Laser Displacement Sensor Data Sheet, from http://www.clrwtr.com/PDF/SUNX/SUNX-LM10-Micro-Laser-Displacement-Sensors.pdf
[18] http://www.scholarpedia.org/article/Tremor#Classifications_of_tremors (visited on october 2010)

Alireza Cheraghizanjani was born in Tehran, Iran on 28th June 1983. He obtained his Bachelor and Master degree in mechanical engineering from Azad University (in 2007) and Universiti Teknologi Malaysia (in 2010), respectively. He is currently prospective Ph.D student. His major field of study is flexible robot control and mechatronics. His research interests include biomedical engineering, vibration control and analyze, robotics, automotive and smart actuators.

Azizan As'arry was born in Kuala Lumpur, Malaysia on the 8th of December 1984. He obtained his Diploma, Bachelor Degree and Master in Mechanical Engineering from the Universiti Teknologi Malaysia, Malaysia, in 2005, 2007 and 2009, respectively. His major field of study is control and mechatronics. He is currently a PhD student in Mechanical Engineering at the Universiti Teknologi Malaysia, Malaysia. His research interests include vibration control, smart actuator, system modeling and simulation and human vibration.

Zulkifli Mohd Yusop was born in Johor, Malaysia on the 19th of October1987. He obtained his Bachelor in Electrical Control and Instrumentation from the Universiti Teknologi Malaysia, Malaysia, in 2009. His major field of study is control and mechatronics. He is currently a Master student in Mechanical Engineering at the Universiti Teknologi Malaysia, Malaysia. His research interests include vibration control, system modeling control system, simulation and human vibration.

Mohd Zarhamdy Md. Zain was born in Perlis, Malaysia on the 8th August 1977. He obtained his Bachelor Degree in Mechanical Engineering from the Universiti Teknologi Malaysia, Malaysia, in 1999 before acquiring Masters of Science and Phylosophy of Doctore qualifications from the University of Sheffield, UK in 2002 and 2006 respectively both in Control Engineering. His major field of study is flexible robot control and mechatronics. He is currently a Senior Lecturer at the Universiti Teknologi Malaysia, Malaysia and his research interests include iterative learning control, applied mechatronics, system modeling and simulation.

Mohamed Hussein graduated from UTM with a Bachelor degree in Mechanical Engineering in 1987 and acquired Masters of Science in Advanced Manufacturing System and Technology from University of Liverpool, UK in 1992. He completed his PhD at the De Montfort University, UK (Leicester) in 2008 in the field of machine control and mechatronics. He is currently an Associated Professor and Head of Department of Applied Mechanics, Faculty of Mechanical Engineering, UTM. His research interests in Mechatronics include machine control, robotics, real-time virtual control and industrial automation.