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TO STUDY AND SAFETY MEASUREMENT OF VIBRATION AND FORCE IN HAND - JACK HAMMER DEMOLISHING MACHINE

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Abstract:

"Hand Jack Hammer Demolishing Machine are widely used in day to day life for cutting concrete along roadside, construction field and industrial areas. The use of hand Jack Hammer Demolishing Machine is very commonly used in every construction / industrial areas. The objective is to study and measure the vibration in hand while operating the hand jack hammer machine. Piezo electric accelerometer is used to measure vibration exposure of HJH in hand during operation. Vibration is measured using battery operated vibration analyzer, connectors, and pulse software for data analysis. Finger TPS – Wireless Tactile force sensor device is utilized or measuring the force exerted at index finger while operating hand Jack Hammer Demolishing Machine with cheveleon TVR software. The results shows that Hand arm vibration magnitude (frequency weighted RMS acceleration values, vibration dose value) are higher in EU's Directive and health guidance with caution zones in IS 5349. The shocks are vibrated to be transmitted along the x-axis to the occupant. Early action values with hand vibration value with hand arm vibration based in A(8) .The operation has the risk of white finger for hand transmitted exposure of more than 3 hours of day, at prevailing operation condition and RMS acceleration is obtained is and 2.25 m/s^2.FTPS is used to measure different parameters during HJH operation at fingers and palm. The maximum force is exerted at index finger during operation is measured to be 1.62kgf. Taguchi approach is made for selection of parameters. HHGTM is measured with and without application of damper to find reduction in force exerted infinger.

Key Words: Hand Jack Hammer, Piezo Electric Accelerometer & Health Guidance

Introduction:

A body is said to vibrate when it describes an oscillating motion about a reference position. The number of times a complete motion cycle takes place during the period of one second is called the frequency and its measured in Hertz (Hz).The motion can consists of a single component occurring at a single frequency, as with a tuning fork, or of several components occurring at different frequencies simultaneously, for example, with the piston motion of an internal combustion engine. Vibration signals in practice usually consist of very many frequencies occurring simultaneously so that we cannot immediately see just by looking at the amplitude-time pattern, how many components there are, and at what frequencies they occur. These components can be revealed by plotting vibration amplitude against frequency. The breaking down of vibration signals into individual frequency components is called frequency analysis, a technique which may be considered the cornerstone of diagnostic vibration measurements. The graph showing the vibration level as a function of frequency is called a frequency spectrogram. When frequency analyzing; we normally find a number of prominent periodic frequency components which are directly related to the fundamental movements of various parts of the hand- arm system. With frequency analysis we are therefore able to track down the source of undesirable vibration. The following definitions are common scientific terms that define vibrational motion:

- Displacement – the distance x of the mass from the equilibrium point at any moment.
- Amplitude – the greatest distance from the equilibrium point.
- Cycle – complete to-and-fro motion from some initial point back to that same point.
- Period – time required for one complete cycle.
- Frequency – number of complete cycles per second, usually specified in Hertz

Human Body Vibration:

Human Body Vibration is a multi-disciplinary subject involving knowledge from disciplines as diverse as engineering, Ergonomics, mathematics, clinical medicine, physics, physiology, and statics. The monitoring and exposure of human vibration is fast becoming a major concern in many industrial workplace environments. This is largely due to increase in occupational injuries caused to exposure to hazardous vibration levels. Many companies required to meet increasing compensation claims in each year because of workers who were exposed to long, continuous vibration, without availability of adequate protection or education. In United States alone, it is reported that there are some 10 million people who are regularly exposed each day to occupational vibration and many more worldwide (Wasserman, 1997) Human Vibration is a physical health hazard and is categorized according to the type of effects it has a specific human body parts which in turn depends on type of job and equipment or machinery being used during work shift. It is divided into whole body vibration (WBV) and hand arm vibration (HAV). WBV occurs when the body is supported on the surface which is vibrating and vibrating effects body parts remote from the site of exposure. some of the principle vibrating equipment are rail transport (cars, trucks, motor cycles, etc.,), off- road Vehicles (Tractors, Excavators, tanks, etc,), marine System(ships, hovercraft ,hydrofoil, submarines, etc,.), industrial (cranes, forklifts trucks), Aerospace system (eg., fixed wing aircraft, rotator wing aircraft), Hand arm Vibration (HAV), affecting workers who use all manner of vibrating pneumatic , electrical , Hydraulic and gasoline powered tools and machineries.

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Hand Arm Vibration:

The transmission of vibration into the hand differs according to the direction of the applied vibration. The effects of vibration within the hand and arm may also depend on the axis of vibration. Vibration is measured on the handle of a tool close to the hand in three orthogonal directions designated x, y, and z (fig 1.4). The axes may be defined relative to the orientation of the hand or relative to the tool. The position and orientation of a hand on a tool may vary. In consequence it is often more convenient to quote the vibration magnitudes relative to three convenient axes of the tool rather than the axes of the hand.

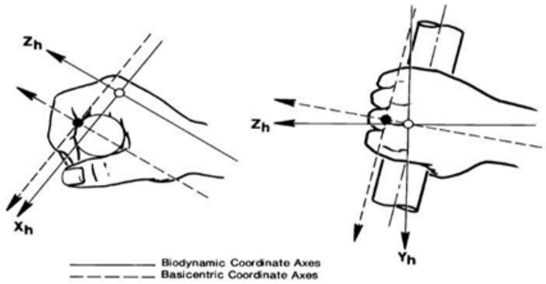

Figure 1: Coordinate system for vibration measurement

As shown above in Figure 1 there are two options in defining coordinate systems based on the respective points of origin. The two coordinate systems that may be used are termed as biodynamic or basicentric coordinate systems (ANSI S2.70-2006).Vibration originating from a tool may be defined as “basicentric motion” which is the maximum vibration from the tool that is available to the worker.

Effects of Hand Arm Vibration:

It has long been recognized that the effects of direct vibration on the human body can be serious. Workers can be affected by blurred vision, loss of balance, loss of concentration etc. In some cases, certain frequencies and levels of vibration can permanently damage internal body organs. The "white finger" syndrome is well known among forest workers handling chain saws. A gradual degeneration of the vascular and nervous tissue takes place so that the worker loses manipulative ability and feeling in the hands. The main health effect from hand-arm vibration is caused by the disruption of blood and oxygen supply to the fingers from prolonged vibration exposure, resulting in damage to blood vessels and nervous system that initially are reversible, it with continued exposure eventually become irreversible. Vibrations from hand-held power tools transmit to the operator’s fingers and may cause tingling and numbness after relatively short period of time. Vibrations caused by hand-held power tools are usually found in the higher frequencies (40 - 300 Hz). With prolonged exposures, structural changes and damage to the peripheral blood supply and nervous systems in the finger occur. Vibrations from hand- held power tools transmit to the operator’s fingers and may cause tingling and numbness after relatively short period of time. In addition, damage to bones, tendons and joints may occur as a result of long term exposure to hand-arm vibration from hand held tools.

Effects of Vibration Parameters:

The principal physical variables influencing the severity of hand transmitted vibration are

- Magnitude of vibration
- Frequency of vibration
- Direction of vibration
- Duration of vibration
- Area of contact
- Contact force
- Finger, hand, arm posture
- Environments (such as temperature)

Health Effects of Vibration:

The hand-arm vibration syndrome causes changes in sensory perception which can lead to permanent numbness of fingers, muscle weakness and, in some cases, bouts of white finger. It is caused by working with vibrating tools. In severe cases a permanent numbness may extend along affected fingers. This may cause clumsiness and difficulty in doing fine tasks. The comprehensive study conducted by NIOSH in 1997 i.e. ‘musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work- related musculoskeletal disorders of the neck, upper extremity, and low back released’ gives an account of correlation between different musculoskeletal disorders and factors attributing it. This may cause clumsiness and difficulty in doing fine tasks. It is caused by working with vibrating tools.

Measurement and Analysis of Hand Arm Vibration:

Experimental Setup:

The main components involved in the experimental setup are accelerometer, vibration analyzer, and data acquisition system. The circuit diagram explains about the experimental setup is shown in the below Figure 4. The accelerometer is placed at the hand-handle interface region and different parts of the operator arm. It acts as a sensor. The accelerometer is connected to the BNC (Bayonet Neill - Concelman) cable and the cable is connected to the LEMO-1B 7 pin connector. This LEMO-1B 7 pin connector is connected to the vibration analyzer. LAN wire is connected in between vibration analyzer and data acquisition system to transmit signals. The sensor will give feedback to the vibration analyzer. The vibration analyzer will convert that signal to the digital signal and given to the data acquisition system. The Data acquisition system consists of dell laptop and pulse lab shop software. The required Output will come from the pulse lab shop software. Accelerometer is made of piezoelectric material and it acts as a sensor in the measurement of vibration exposure. The specifications of accelerometer are shown in the Table 3.3.1. The accelerometer with cable and connector is shown in the Figure 2. It must be placed in the up direction as marked in the accelerometer.

Figure 2: Accelerometer with Cable and Connector

Features:

- Robust titanium housing with integrated titanium connector
- Easily fitted to different test objects using a selection of mounting clips
- Low-weight design giving high sensitivity/weight ratio Tri-axial mounting facility
- Operating temperature up to 250 degree Celsius

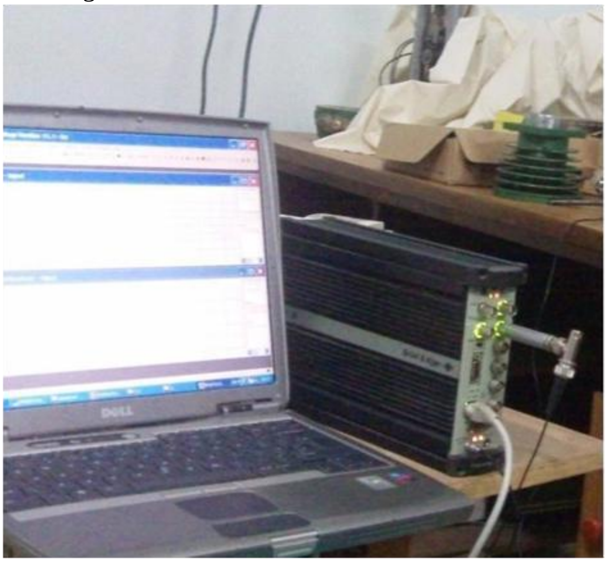

Figure 3: Experimental setup

The sensor will give feedback to the k=976 vibration analyzer. The vibration analyzer will convert that signal to the digital signal and given to the data acquisition system. The Data acquisition system consists of dell laptop and pulse lab shop software. The required Output can be selected using the pulse lab shop software.

Accelerometer:

Miniature Delta Tron Accelerometers types 4507B are specifically designed to withstand the rough environment of the industries. A combination of high Sensitivity, low mass and small physical dimensions make them ideal for modal Measurements.

Description	
Type/make	B & K type 4507B M/s Bruel and kjaer sound and vibration measuring instrument A/s Denmark
Sensitivity	10 mv/g
Connector	LEMO-1B BNC, 1feet 7 pin to
Cable	Single screen coax, 10-32 UNF to BNC, 5m

Table 1: Specification of Accelerometer

Vibration Analyzer:

Type 3560 is a very easy-to-use, rugged, portable human vibration analyzer, Designed primarily for use in health and safety field. The compact housing lies perfectly in your hands and operation can be simpler. The vibration analyzer uses battery / DC power for operation. It consists of 5 input channels and one output channel. The unit handles communication with the PC. This analyses different working scenarios to identify health risks and find solutions for reducing vibration exposure and is transform this information into pulse Lab shop software. The vibration analyzer is shown in the figure 4.

Features:

- Tabulated over a range of octave band central frequencies.
- Simultaneous measurement of 5 channels @ 25.6 KHz frequency range Compact, robust casing for industrial and hard

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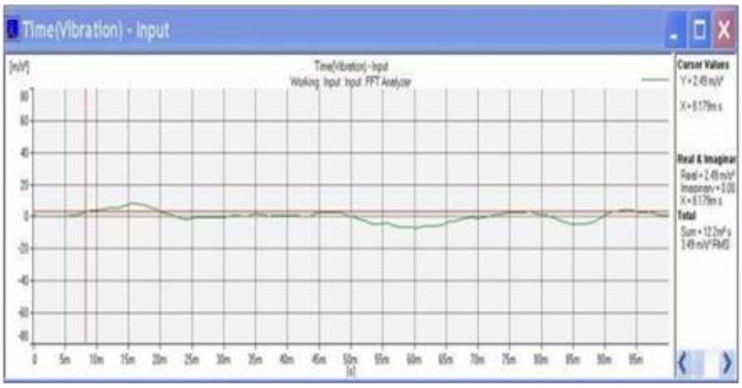
everyday use

- Battery operated (5 hours continuous) or DC powered (10 -32 V)
- Silent operation to 35 degree Celsius Cooling fans can be turned off for silent operation (auto- restart if too hot) Synchronous sampling with other PULSE front-ends

Figure 4: Vibration Analyzer

Pulse Lab Shop Software:

Pulse Lab shop is a vibrations measuring software. The whole body vibrations and hand arm vibrations are measured using this software. This software is developed by the Bruel & Kjaer. The most basic vibrations measurements that can be made are Time signal and Spectrum analysis. The accelerometer can be attached to anything that the vibration spectrum or time response canbe measured. A simple setup may involve mounting an accelerometer to a table and the response of the tapping the table can be measured. In order for measurements to be made with Pulse, a transducer has to be connected to one of the inputs of the analyzer. The sample outputs from B&K data acquisition (PULSE Lab shop) software are shown in the figure 7. It gives the maximum acceleration values for given input frequency levels. There are two main graphs in the output came from the pulse Lab shop software. One is frequency vs. maximum acceleration and the other one is time Vs maximum acceleration. The values are



The methodology adopted for this project work is portrayed in figure 5. A detailed literature review has been carried to recognize and assess the problem. The earlier stages of work are concentrated on familiarising the vibration measurement using B&K vibration analyser.

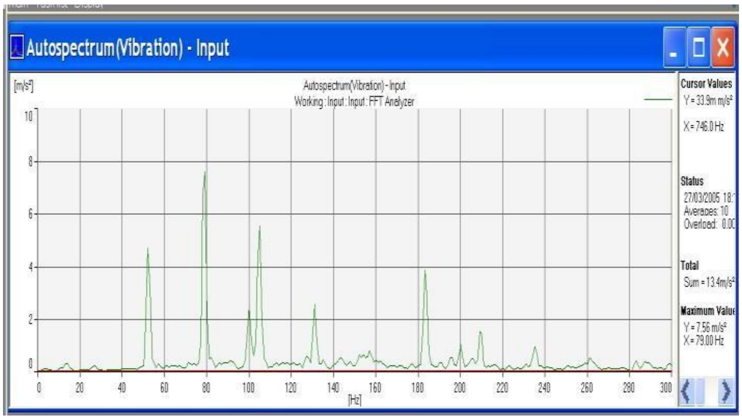


Figure 5: Sample Output from Bruel and Kjaer Data Acquisition (Pulse Lab shop) Software

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The accelerometer (B & K) senses the vibrations are the data is further processed by the analyser and PULSE Labshop software. The sensor is used to measure forces acting on fingers during operation. Experimental Studies are conducted at fingers and palm throughout the operation. Analysis of characteristics of transmitted vibrations are carried out and based on the findings recommendations are made to control the vibration hazard.

Taguchi Approach:

The Taughi method is a well-known technique that provides a systematic and efficient methodology for design optimization. It is a widely used for product design and process optimization world-wide. This is due to the advantage of the design of experiment using Taughi's technique that includes simplification of experiment plan and feasibility of study of interaction between different parameters. Lesser number of experiments means reduction in time and costs. Taguchi proposed experimental plan in terms of orthogonal array that gives different combinations of parameters and their levels for each experiment. According to this technique, the entire parameter space is studied with minimal number of necessary experiments only.

Subjects:

Five healthy unprofessional tool uses are chosen for this study the subject was first explained the test procedure, and made acquainted prior to the experiment. For first trial, the subject needed to use 150 mm nylon wire while vibration is measured and next trial it needed to run at 300mm of nylon wire. The physical characteristics of the subject measured for accelerometer during are given in table 2.

Dimensions	Subject 1
Hand length	221
Breadth at metacarpal	82
circumference at wrist	180
Circumference at elbow	285
Lower arm length	300

Table 2: Subjects' hand-arm anthropometric data (all dimensions are in mm)

Finger-TPS (Tactile Pressure Sensing):

Finger TPS Wireless Tactile Force Measurement System. The all-new, redesigned Finger TPS (Finger Tactile Pressure Sensing) System utilizes highly sensitive capacitive-based pressure sensors to reliably quantify forces applied by the human hand. It's the only practical and comfortable sensor solution that also connects wirelessly to your PC. With our powerful new Chameleon software, Finger TPS Systems can be easily reconfigured and recalibrated for different uses of the hands on the fly. Finger TPS Systems also include synchronized video recording to match tactile data with actual use. Precise force data and video images can be captured and displayed in real- time via PPS's Chameleon Software, which has Tivo - like versatility in recording time- series, average and peak force measurements.

System Contents:

A Standard System Consists of

- Finger T PS sensors
- 2 pieces of Acrylic Stand
- Capsense wrist Module
- Rechargeable Wireless Bluetooth Interface Electronics box

Figure 6: Wireless Finger TPS system Components

- Calibration and Reference Load cell
- Bluetooth Dongle
- USB to mini USB cable for recharging
- Hi-Res USB Logitech 2.0 Camera

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Figure 7: Sensors setting up on fingers

Main Program Screen:

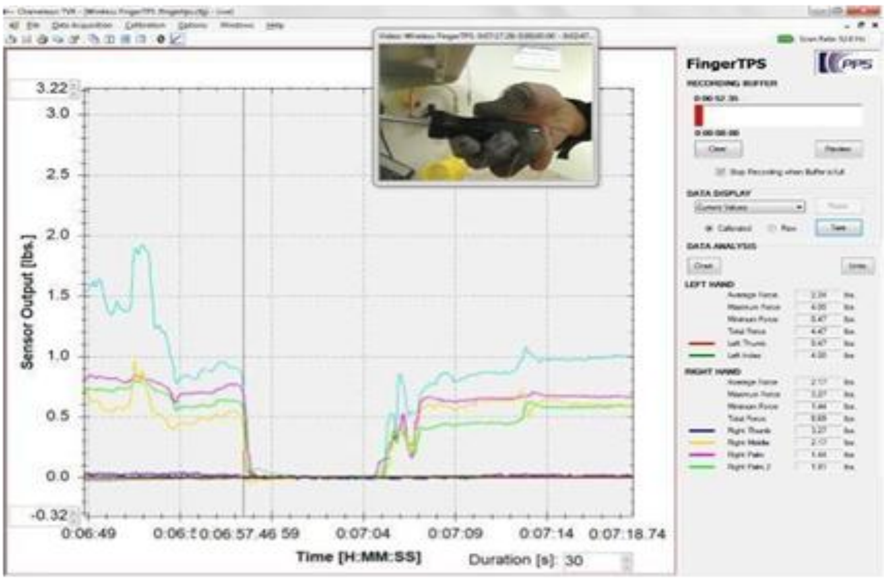


Figure 8: Main Program Screen

Setting Up Sensors & Hardware:

It is recommended that two people be involved in setting up the Finger TPS system. One person can perform the experiment, while the other assists in fitting the system and controlling the data acquisition software.

- Attach the Finger TPS Rechargeable Wireless Bluetooth Interface Box to the back of the operator's belt, pocket or waistband.
- Connect the Capsense Wrist Module cable to the Rechargeable Wireless Interface Box
- Fasten the Capsense Wrist Module around the wrist(s) of the hand(s) the sensors will be used.

Setting up the Finger TPS Sensors:

The finger sensors are carefully crafted for pressure measurements. Care must be taken in putting them on, using them and storing them. The sensing element (Sensor Front) will be used for pressure measurements and will be worn on the grasping side of your hand(s). The sensing element is physically located 2mm within the oval shaped stitch pattern on the Sensor Front. No sensing elements are located on the back of the sensor and should not be loaded.

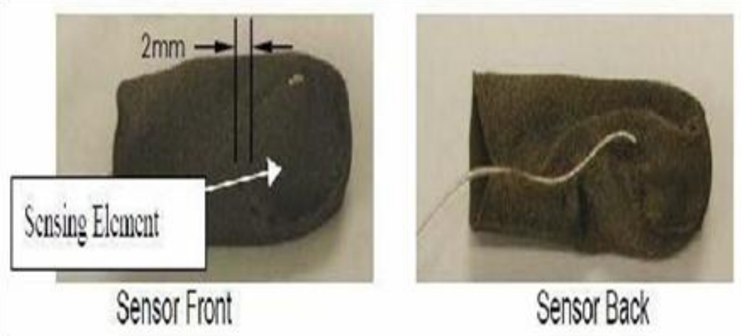
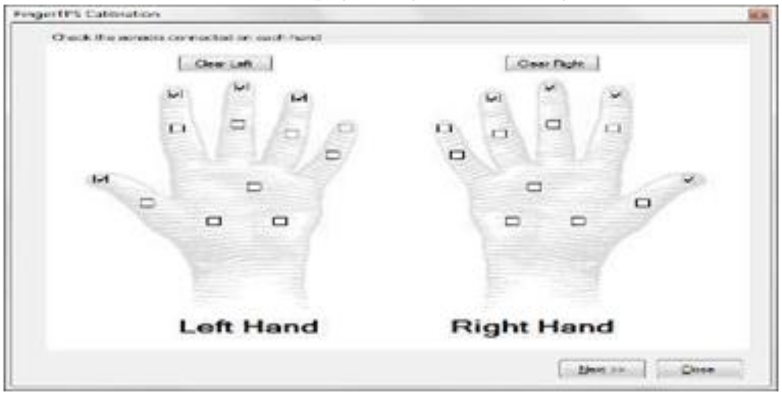


Figure 9: Placing of Sensors

Calibration Procedure:

PPS Visualizer Software allows for easy calibration of the Finger TPS sensors. To begin calibration, go to menu Data Acquisition / Calibrate System. Select the sensors that are physically available to you and click Next to start calibration.



Results and Discussions:

Vibration Magnitude:

This section discusses the vibration magnitudes obtained at palm, metacarpal, wrist and elbow while performing the drilling operation. During the operation elbow is kept perpendicular to the forearm. The vibration measurement is calculated for the drilling of 8 mm hole in an aluminium material

Frequency Weighted RMS Accelerations at Palm:

Accelerations at palm refers to the vibration magnitudes at hand- handle interface while performing the hand jack hammer operation. They are measured by placing accelerometer at hand- handle interface Average total frequency weighted rms acceleration obtained at palm is $6.44 m/s^2$. Average total frequency weighted rms acceleration measured along x, y and z directions are $3.6 m/s^2$, $4.478 m/s^2$ and $2.924 m/s^2$ respectively. Subjective variability in acceleration values are found to be significant.

Axis	Subject 2
X axis	3.53
Y axis	3.78
Z axis	3.89
Total	6.471

Table 3: Frequency weighted rms accelerations at palm m/s^2

With an exposure level of $6.471 m/s^2$, time to reach, Exposure Action Value (EAV).

Analysis of Hand Transmitted Vibrations Using Finger-TPS with Various Process Parameters:

Discussion on Ex. No. A - Forces at Index Finger and Palm:

During operation of hand jack hammer it is found that the load is to be applied by index finger, so the maximum force is exerted in index finger. Firstly, the hand Jack Hammer Demolishing Machine is operated without adding damper material. The maximum value exerted in index finger is 0.40 kgf is acting throughout the operation and total force acting on index and thumb are 0.78 kgf are is shown in fig 10, 11 & 12 respectively. Secondly, the hand jackhammer is operated with the addition of damper material. The maximum value exerted in index finger is 0.28 kgf is acting throughout the operation is shown in figure 12.

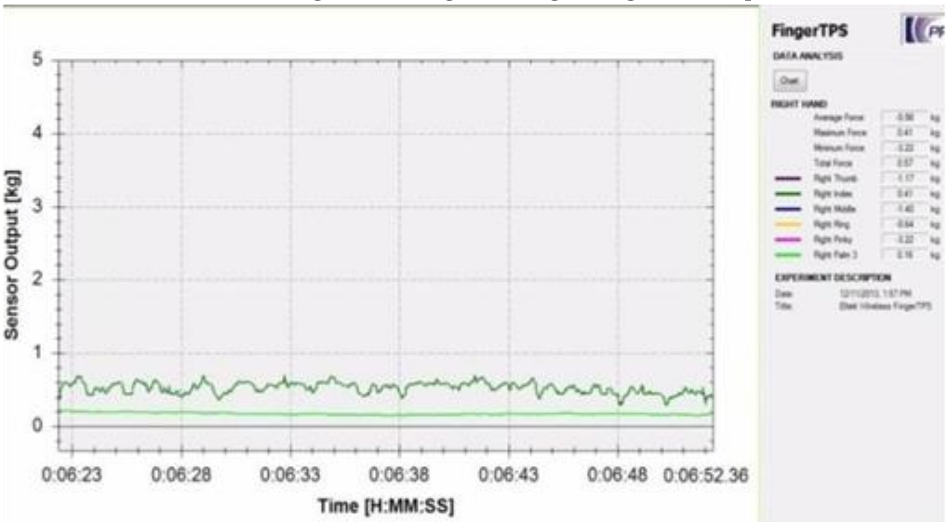


Figure 10: Ex. No. A without Damper

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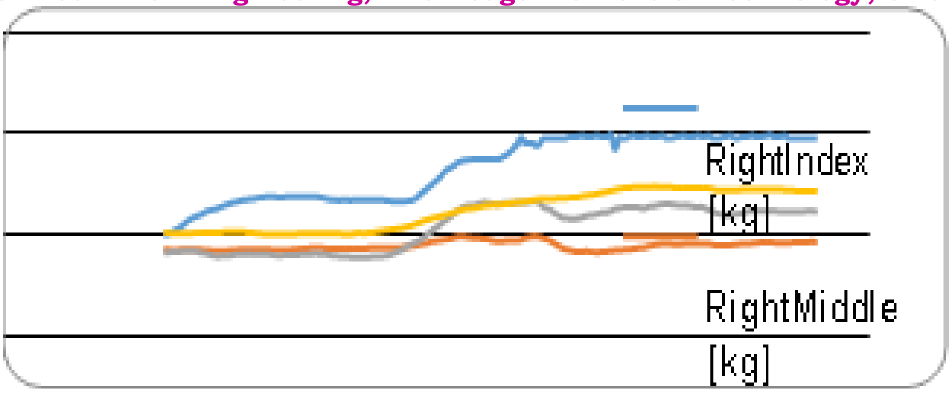


Figure 11: Ex. No. A without Damper (1)

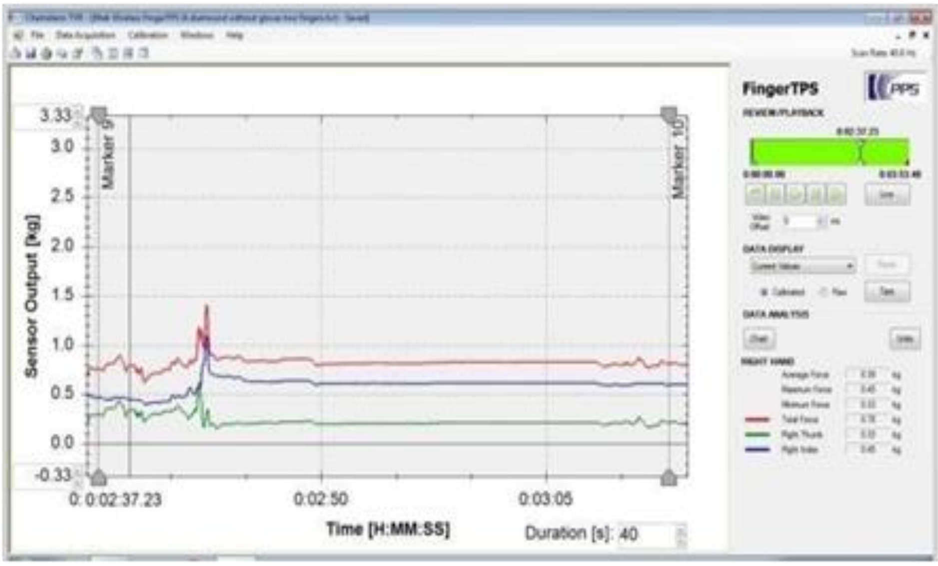


Figure 12: Ex. No. A without Damper (1)

Discussion on Ex. No. B - Forces at Index Finger and Palm:

During operation of hand jack hammer it is found that the maximum load is acting index finger, so the maximum force is exerted at index finger. Firstly, the hand jack hammer is operated without adding damper material. The maximum value exerted in index finger is 0.62 kgf acting throughout the operation and total force acting on index and thumb are 0.83 kgf shown in fig 13 and 14 respectively. Secondly, the hand Jack Hammer Demolishing Machine is operated with the addition of damper material. The maximum value exerted in index finger is 0.30 kgf and 0.25 kgf at right thumb are acting throughout the operation is shown in fig 15.

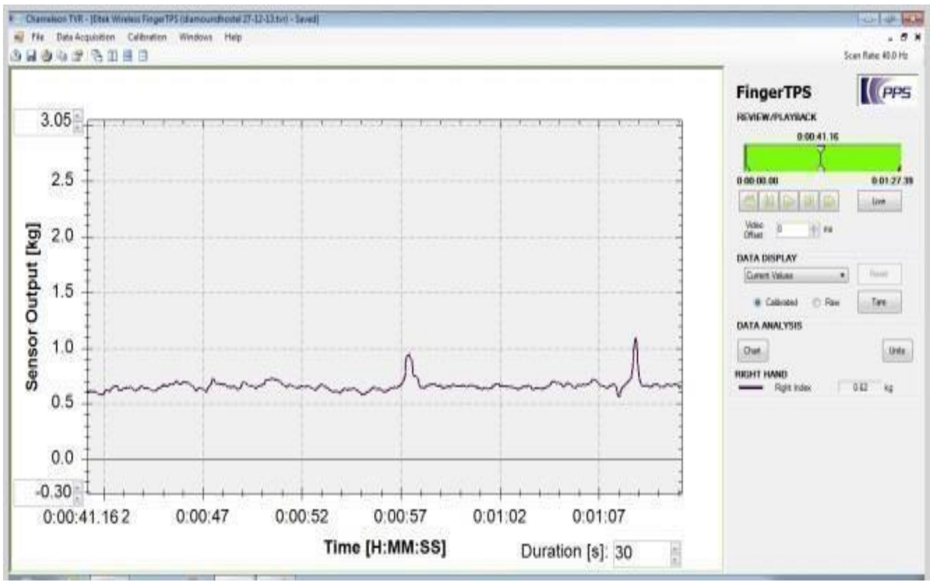


Figure 13: Ex. No. B without Damper (2)

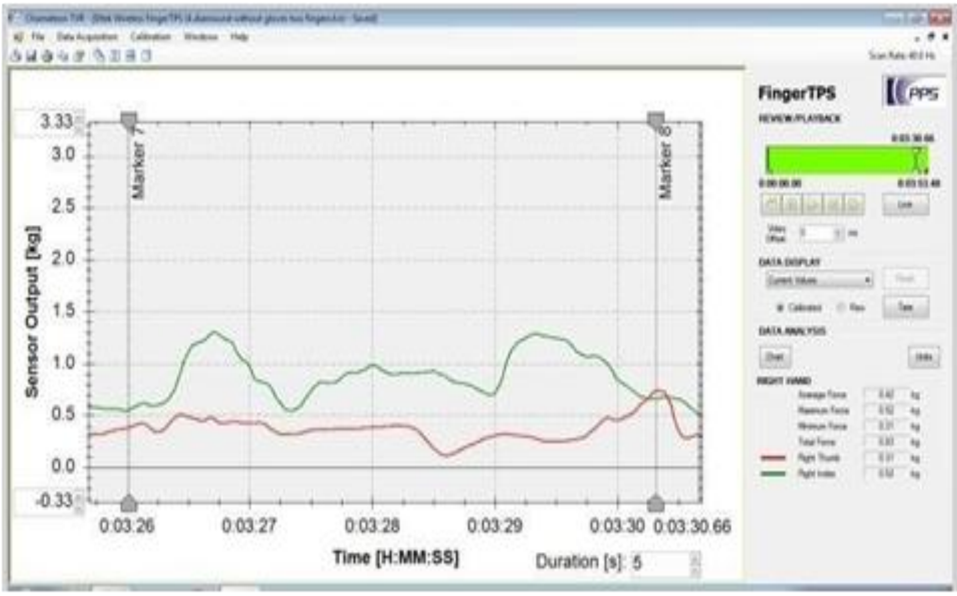
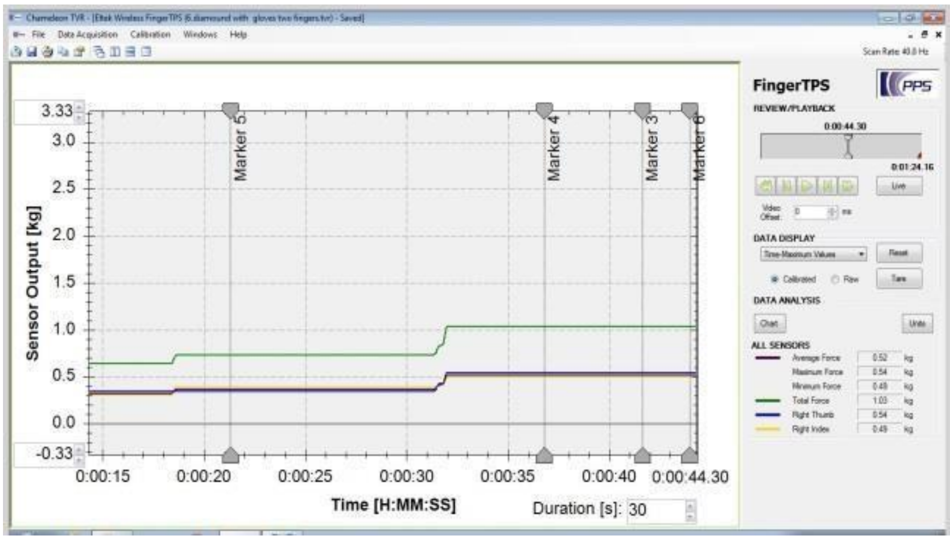


Figure 14: Ex. No. B without Damper (3)



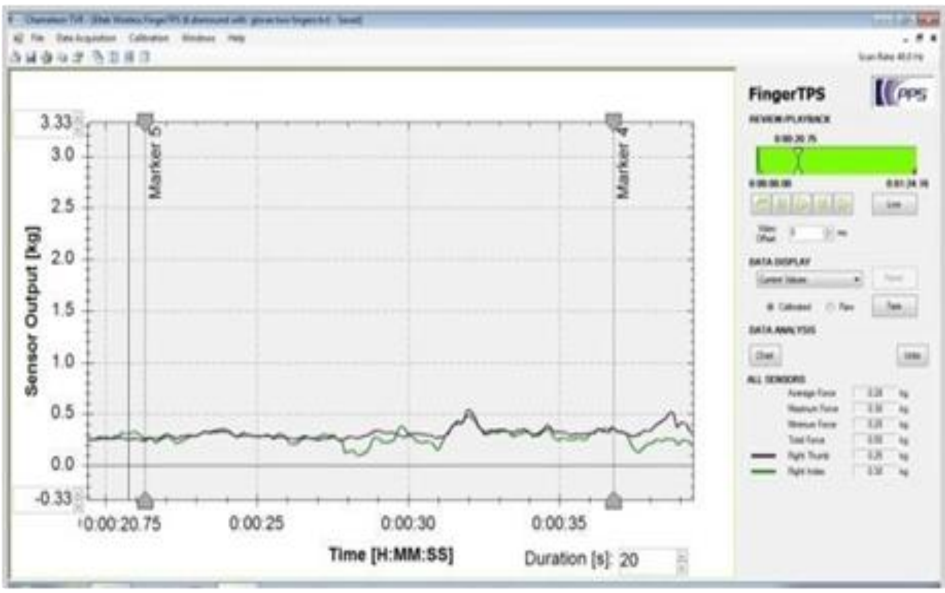


Figure 15: Ex. No. B with Damper (2)

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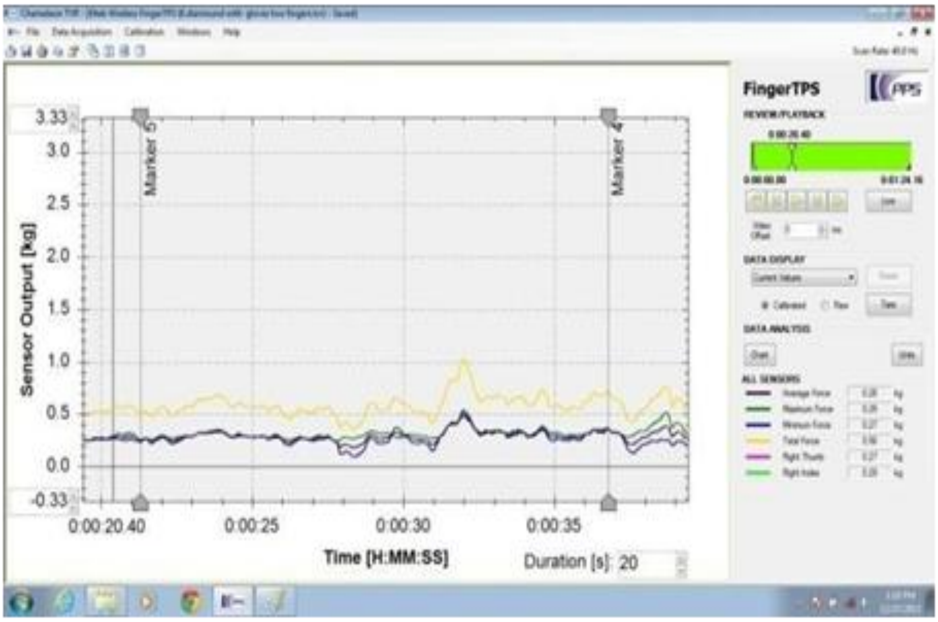

Figure 16: Ex. No. B with Damper (3)

Analysis of Hand Transmitted Vibration Using Finger-TPS:

Analysis of operators' exposure to hand transmitted vibration shows that the Jack Hammer Demolishing Machine produces high level of vibration and hence it is not suitable for continuous occupations without damper. Hence vibration measured at index finger is high. As the distance of vibration location increases from source the magnitude of vibration diminishes, this is particularly witnessed at higher frequency component. The study reveals that vibration exposed to index finger is more than other fingers.

Conclusion:

This research is an experimental investigation on characteristics of hand transmitted vibrations during hand jack hammer Operation. Experiments are carried out to determine the vibration levels at palm. The readings from accelerometer are analysed using B&K vibration analyser and further processed by PULSE Lab shop software. An attempt is made to quantify the risk involved in operating such a machines. It is revealed that an increased exposure will cause Hand arm vibration Syndrome. The Maximum force exerted in index finger during operation is 0.62 Kgf. The magnitude of vibration reduces with increasing in measurement location distance from source of vibration. At the same time resonance occurs around 28, 56, 85 and 100 Hz frequencies. The analysis of transmitted vibration shows that hand-arm system can isolate higher frequency vibrations. It is ineffective in attenuating vibrations below100Hz. The result clearly indicates that operator and machine should be given prior gap between every 3 hours. The results obtained from the above studies clearly prove the possibilities of frequent back pain and HAVS. According to calculated values, very high levels of adverse health effects are predicated for heavy mobile machine operators. Occupational Exposure to HAV and physical factors at work are important components of the multifunctional origin of physiological effects in professional machinery operators.

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