PENDEDAHAN GETARAN MESIN GERGAJI BERANTAI TERRHADAP LENGAN DAN TANGAN

(HAND ARM VIBRATION EXPOSURE OF THE CHAINSAW MACHINE)

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ABSTRAK

Projek ini mempamerkan keputusan eksperimen berkenaan getaran yang dipindahkan daripada gergaji rantai ke tangan manusia. Penghasilan getaran daripada gergaji rantai ini diukur pada gagang hadapan dan belakang, dengan setiap gagang diukur dari posisi 3 paksi biodinamik yang sejajar dengan piawaian ISO 5349 (1986). Bagi tujuan ini, 3 mod operasi telah diimplementasi berdasarkan piawaian ISO 7505 (1986) iaitu pemelahuan, lumbaan dan pemotongan. Operasi pemelahuan dan lumbaan tidak melibatkan persentuhan antara kayu dan gergaji sementara bagi operasi pemotongan, gergaji akan memotong kayu pada 2 arah iaitu secara melintang dan membujur. Teknik pemotongan membujur (*bucking*) dan melintang (*felling*) diadaptasikan daripada kerja pengukuran getaran di kawasan hutan .

Bagi pemotongan membujur, langkah awal melibatkan penetapan log kayu pada kedudukan melintang di atas meja kerja dan diapit pada kedua-dua belah untuk mengelakkan sebarang pergerakan. Operasi pemotongan dilakukan pada tiga sudut yang berlainan; 0°, 30° dan 45°. Bagi setiap sudut, gergaji rantai akan memotong log kayu pada 3 tahap kelajuan yang berbeza; 750 rpm, 980 rpm, dan 1220 rpm masing-masing. Getaran diukur dengan menggunakan meter getaran bersepadu dan nilai yang diperolehi berbentuk pecutan berpemberat frekuensi dalam unit m/s^2. Langkah yang serupa diikuti bagi pemotongan secara melintang di mana log kayu diletakkan pada kedudukan membujur sebelum pemotongan dijalankan.

Bagi operasi pemelahuan, nilai getaran yang diperolehi adalah paling dominan pada paksi-z dengan nilai 14.7 m/s^2 yang wujud pada gagang belakang manakala bagi operasi pemelahuan pula, nilai getaran adalah paling dominan pada paksi-x dengan nilai 18.7 m/s^2 di gagang hadapan gergaji rantai. Dalam operasi pemotongan, nilai getaran yang terhasil tidak hanya bergantung pada kelajuan pemotongan malahan banyak dipengaruhi oleh faktor-faktor seperti saiz sudut, keadaan log kayu, dan sebagainya. Maklumat yang didapati daripada pemecutan getaran mampu menambahkan pengetahuan berkaitan pemindahan getaran daripada peralatan seperti gergaji rantai ke atas tangan manusia serta membantu pembangunan peranti yang mengurangkan getaran.

ABSTRACT

This project presents experiment results of the hand arm vibration transmitted from the chainsaw. The vibration emitted from the chainsaw taken at front and rear handle for three biodynamic axes which represents in accordance with ISO 5349 (1986). For this purpose, three operational modes were implemented; idling, racing and cutting based on ISO 7505 (1986). Idling and racing does not involve any contact with the logs while cutting operation is carried out at 2 direction; vertical and horizontal cutting. Vertical (bucking) and horizontal (felling) cutting techniques were adopted from forestry work.

For vertical cutting, initial steps involved logs positioned horizontally on a work bench and clamped at both sides to prevent movement. Cutting operations were done at 3 different angles; 0°, 30° and 45°. For each angle, vibration measurements were done in 3 different speed of rotating chain/cutter; 750 rpm, 980 rpm, and 1220 rpm. The vibration measurements were obtained in the form of frequency-weighted acceleration, given in ms^{-2} using integrating vibration meter. Similar steps were followed for horizontal cutting where logs were positioned vertically prior to cutting.

For idling operation, the dominant axis was the z axis with value of 14.7 m/s^2 which occurred in rear handle. For the second operation or the racing operation the dominant axis was the x axis wit value of vibration of 18.7 m/s^2 occurred at front handle of the chainsaw. In cutting operation, the value of vibration does not depend only on cutting speed. The values of the hand arm vibration are also influenced by factors such as angle, logs condition and few others. Knowledge of vibration acceleration value may increase the understanding of vibration transmission from forestry machinery such as chainsaw to human hand and aid in the development of effective isolation devices.

CHAPTER 1: INTRODUCTION

1.1 Definition of Hand Arm Vibration Exposure

Any motion that repeats itself after an interval of time is called vibration or oscillation. If you could watch a vibrating object in slow motion, you can see movements in different directions. How far and how fast the object moves helps determine its vibrational characteristics. The terms used to describe this movement are frequency, amplitude and acceleration.

Contact with a vibrating machine transfers vibration energy to a person's body. Depending on how the exposure occurs, vibration may affect a major part of the worker's body or only a particular organ. The effect of vibration exposure also depends on the frequency of vibration. Each organ of the body has its own resonant frequency. If exposure occurs at or near any of these resonant frequencies, the resulting effect is greatly increased.

Segmental vibration exposure affects an organ, part or "segment" of the body. The most widely studied and most common type of segmental vibration exposure is hand-arm vibration exposure which affects the hands and arms. **Hand-arm vibration** affects operators of chain saws, chipping tools, jackhammers, jack leg drills, grinders and many other workers who operate hand-held vibrating tools. This project involves measurement of hand arm vibration in chain saw operator.

1.2 Overview of Chainsaw Operation

Chainsaws are powerful and valuable tools. They can be found on most commercial workplace in our country where trees or logs is cut for multiple purposes. It is also the principal cutting tool for most of the commercial timber produced in Malaysia. Contractors use them for cutting large timbers, crossties and landscaping ties as well as land clearing.

However, despite the benefits of chainsaw use, the potential for accidents while using a chainsaw is high, and injuries sustained are usually severe. This usually occurs in the hands of a careless, inexperienced or tired operator. The Consumer Product Safety Commission found that the number of chainsaw accidents requiring medical attention increased from 70,000 to 135,000 annually over a five-year period. These accidents appear to be increasing at the alarming rate of 10 percent per year**. (University of Minnesota, 1989).** Most accidents were caused when the operator came in contact with a moving chain. Injuries from a chain saw are usually serious because of the jagged cut the chain leaves. Proper clothing and personal protective equipment is as important in reducing the risk of injury as knowing the specifications and operating parameters of the saw.

The long-term effects of chainsaw vibration on a worker's fingers, hands and arms are often not recognized. Although there are frequent usage of gasoline operated chainsaw in timber or sawmill operation in our country, there is still lack of research made on the hand arm vibration transmitted to the operator. Therefore this project is carried out to measure the hand –arm vibration exposed to the operators. This is due to hand-arm vibration syndrome being experienced by the operators. The hand-arm vibration syndrome induced by regular use of vibratory tools, such as chain-saws, includes multisystemic symptoms and signs suggesting the involvement of peripheral circulation, bone, muscles and the central and peripheral nervous systems. In the early stages of the hand-arm vibration-syndrome, a specific neurological disturbance are common, they include relapsing or almost continuous paraesthesia, numbness and pain in the hands and often worsening at night. **(Fabio Gianini, 1999)**

1.3 <u>Objective of Project</u>

This project is mainly carried out to achieve the purpose stated below:

a) To understand the phenomena hand arm vibration in hand held power tool (chainsaw).
b) To learn the methods of operation involving equipment and device to measure hand transmitted vibration.
c) Measurement of the hand arm vibration of the operator during operation at different parameters.

1.4 Project Layout

First of all, Hand Arm Vibration (HAV) syndrome is well understood in vibratory tools especially in chain saw equipment. For that, relevant journals and other references are obtained on HAV phenomena, vibration values on various tools, experimental procedures such as measuring vibration i.e biodynamic axes and method of operating chain saw. Furthermore, knowledge on vibration measurement carried out in forestry work is also gained to form comparison with the project. Other than that, particulars about the standard related to HAVs and safety measures taken during operating the chain saw are compiled and understood. Prior to the experiment, few logs of soft wood called '*setang*' in Malay are chosen and obtained. An aluminium plate is to be fabricated into blocks to mount the accelerometer in 3 axes based on biodynamic axes. The fabricated blocks are then attached to the handles of chain saw in separate occasions. Chain saw used for the project is from model Husqvarna 350. Few L-shaped thick steel plates are to be fabricated to serve as support for the logs to remain in static position. The L-shaped plates will then be attached to the logs by nailing and clamped on the working table using C-clamp. Prior to cutting, idling measurement of the chain saw is taken. Logs are positioned horizontally and vertically in separate occasion during measurement. Vibration measurements are obtained in different axes using various speed and different cutting angles using chain saw. During measurement, tachometer functions as device to measure speed of the chain. In other hand, accelerometer means to measure the acceleration of vibration at all 3 axes. Datas are collected, compiled, analyzed and discussed based graphs plotted. Problem that occurs (if any) during the project are troubleshooted at its stages before further proceedings. A flowchart in following page is presented to summarize the activity layout of the project.

1.5 Project Layout Flow Chart

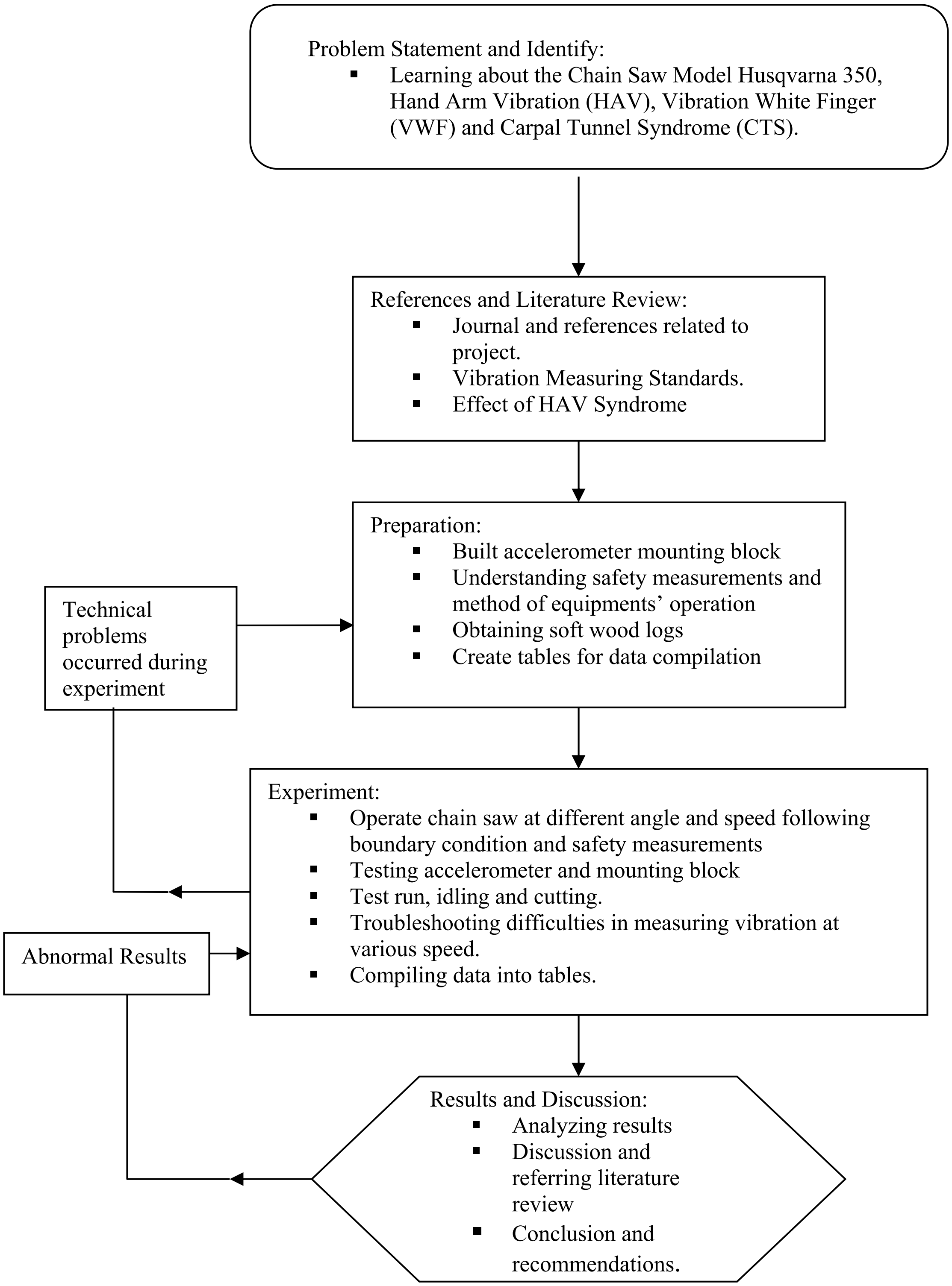

Figure 1.1: Schematic Flow Chart of Project Layout.

CHAPTER 2: LITERATURE REVIEW

2.1 Hand Arm Vibration

2.1.2 Overview

Hand-Arm Vibration is defined as the transfer of vibration from a tool to a worker's hand and arm. The amount of HAV is characterized by the acceleration level of the tool when grasped by the worker and in use. The vibration is typically measured on the handle of tool while in use to determine the acceleration levels transferred to the operator. The long-term effects of machine, equipment or material vibration on a worker's fingers, hands and arms are often not recognized. Significant vibration is a concern in many situations in forestry jobs. The operation of a chainsaw is a good example.

Hand-arm vibration syndrome (HAVs) is a widespread industrial disease affecting tens of thousands of workers. Exposure to hand-arm vibrations over a number of years can result in permanent physical damage commonly known as '**raynauds disease'** or '**white finger syndrome'**, or the vibration can damage the muscles and joints of the wrist and elbow.

Its best known effect is vibration-induced white finger (VWF). Early symptoms of raynauds disease include pain, tingling, numbness, and loss of feeling and control in the fingers, followed by blanching of the fingers caused by damage to the arteries and nerves in the hands. **[Zinck, 1997].** Attacks are painful and can result in the loss of the ability to grip properly. Any vibrating tool or process which causes tingling or numbness after 5-10 minutes is suspect **[www.hse.gov.uk].**

Regular exposure to HAV can cause a range of permanent injuries to your hands and arms, which are known as hand-arm vibration syndrome (HAVs). The injuries you could suffer include damage to your blood circulatory system, sensory nerves, muscles, bones and joints. Table below summarizes the factors that influence the severity of hand arm vibration syndrome **[Barber, 1992].** Vibration absorbing gloves and vibration absorbing material is wrapped around the handles of power tools in order to reduce the hand-transmitted vibration **[Zinck, 1997].**

Table 2.1: Factors that influence the effect of vibration on the hand

Physical Factors	**Biodynamic Factors**	**Individual factors**
Acceleration of vibration.	Grip forces - how hard the worker grasps the vibrating equipment.	Operator's control of tool
Frequency of vibration.	Surface area, location, and mass of parts of the hand in contact with the source of vibration	Machine work rate
Duration of exposure each workday.	Hardness of the material being contacted by the hand-held tools, for example metal in grinding and chipping	Skill and productivity
Years of employment involving vibration exposure.	Position of the hand and arm relative to the body	Individual susceptibility to vibration
State of tool maintenance.	Texture of handle-soft and compliant versus rigid material	Smoking and use of drugs.
Protective practices and equipment including gloves, boots, work-rest periods	Medical history of injury to fingers and hands, particularly frostbite	Disease or prior injury to the fingers or hands

2.2 Hand Arm Vibration Health Effects

Excessive exposure to hand-transmitted vibration can cause disorders in the blood vessels, nerves, muscles, and bones. This could be connected to various diseases.

2.2.1 Vibration-induced white finger (VWF)

Vibration-induced white finger (VWF) or known as Raynaud's phenomenon is the most common condition among the operators of hand-held vibrating tools. Vibration can cause changes in tendons, muscles, bones and joints, and can affect the nervous system. Collectively, these effects are known as Hand-Arm Vibration Syndrome (HAVs). The symptoms of VWF are aggravated when the hands are exposed to cold. Workers affected by HAVs commonly report **[www.ccohs.ca/oshanswers/phys_agents/vibration/vibration_effects.html]**:

- attacks of whitening (blanching) of one or more fingers when exposed to cold
- tingling and loss of sensation in the fingers
- loss of light touch
- pain and cold sensations between periodic white finger attacks
- loss of grip strength
- bone cysts in fingers and wrists

Figure 2.1: White finger syndrome **[www.whitefinger.co.uk]**

2.2.2 Carpal Tunnel Syndrome

Carpal tunnel syndrome is a disorder due to compression of the median nerve as it passes through the palm side of wrist. Carpal Tunnel Syndrome seems to be a common disorder in some occupational groups using vibrating tools, such as rock-drillers, pneumatic screwdrivers and forestry workers. It is believed that repetitive movements, forceful gripping and awkward postures, in addition to vibration, can cause Carpal Tunnel Syndrome in workers handling vibrating tools. One of the symptoms, operators may complain muscle weakness and pain in hand and arms. In some individuals muscle fatigue can cause disability.

2.3 Chain saw Machine Description

2.3.1 Rear-Handled Chain saw

Chain saws have become an everyday tool for a wide variety of individuals. Homeowners use them to cut firewood and to do general tree trimming around their homes. Farmers find them useful for such jobs as clearing land, trimming trees and cutting firewood. Contractors use them for cutting large timbers and landscaping ties as well as land clearing. Rear-handled Chain saws have the rear handle projecting from the back of the saw. They are designed to always be gripped with both hands, with the right hand on the rear handle.

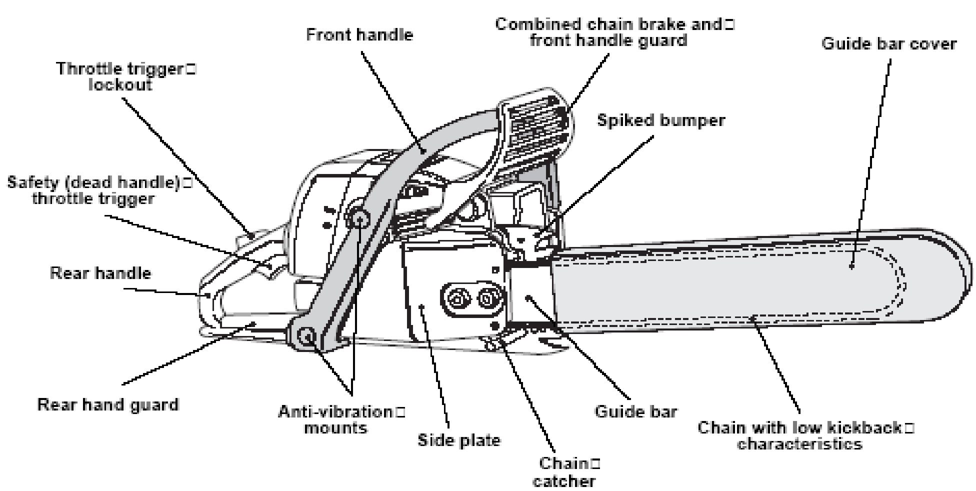

Figure 2.2: Basic Chain saw diagram **[www.hse.gov.uk]**

In order to reduce the risk of injuries of chainsaw operators, manufacturers revitalized old designs. Few safety features have been taken into account in modern chainsaws. Modern chainsaw features:

- **Front hand guard**
  A bar in front of the top handle designed to stop a slipping hand from coming in contact with the chain.
- **Chain brake (gasoline only)**
  Designed to stop a moving chain in a fraction of a second if kickback occurs, reducing the chances of severe injury. May also function as a front hand guard.
- **Throttle trigger lockout**
  Prevents the accidental opening of the throttle. The throttle trigger is locked in the idling position when the lockout is not engaged by the proper hand grip on the handle.
- **Stop switch**
  Should be located so that it can be activated easily by your right thumb without losing your grip on the rear handle of the saw.
- **Rear hand guard**
  The lower part of the rear handle on the chain saw is designed to protect the hand from a broken or jumping chain.
- **Chain catcher**
  Found on the bottom of the saw engine as far forward as possible. It is designed to catch a broken or jumping chain.
- **Vibration damping**
  Rubber bushings between the handle and saw body or on the engine mountings help reduce the operator's exposure to vibration.
- **Muffler**
  Designed to decrease the noise level and direct hot exhaust gases away from the operator. This may be combined with the spark arrester.

The type of chain saw used in this project is Husqvarna model 340.

Figure 2.3: Husqvarna 340 rear-handled model chainsaw

It's a chain saw for light farm and small property owners. It's powered by gasoline engine which requires petrol and 2-stroke lubricant oil. Equipped with features such as combined choke/stop button control making it easy to start and stop, Eco-pump and Air Injection. This machine is design suits the right hand dominant users. Where the right hand holds the rear or throttle handle and the left hand holds the front handle.

The speed of the cutting is controlled by the feed force of the throttle. The cutting speed also determined by type of wood (softwood or hardwood), chain sharpness and engine power.

2.3.2 Other Model Comparison

These saws have the rear handle over the top of the engine. They are not designed for use on the ground or as a substitute for small, rear-handled chainsaws. This type chain saw was another type of chain saw used in experiment conducted by **[Paul Pitts, 2004].** The model used in the experiment was form Stihl top-handled chain saw. It has following characteristics:

- Engine size 35.2 cm^3
- Power 1.7 kW
- Guide bar range 30 - 35 cm
- Weight without chain and bar 3.5 kg
- Declared emission values Front: 3.4 m/s^2, Rear: 5.3 m/s^2

Figure 2.4: Top-Handled Chainsaw **[www.Northerntool.com]**

Second example is the electrical powered chainsaw by Remington an America based company specializing in electrical chain saw manufacturing. One of the model produced is model 076728 type. This is the mid-size price point electric saw that has the power and bar length to handle many cutting chores such as limbing and trimming. It has following characteristics:

- 1.5 peak horse power
- 12 inch bar
- handling weight of 4.56 Ibs

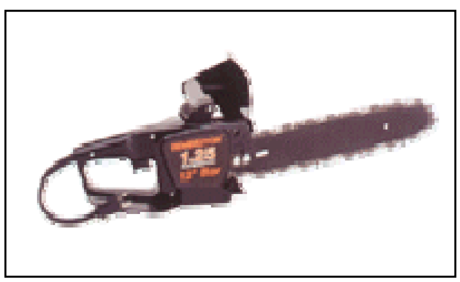

Figure 2.5: Electric Powered Chainsaw **[www.Remington.com]**

2.4 Relevant studies

V.Goglia (2003) has carried out a research on hand-transmitted vibration form steering wheel to drivers of a small four-wheel drive tractor. It is known that the vibration entering the hand contains contributions from all three measurement directions. Therefore, the measurement made for all three directions simultaneously. Measurement was done 3 directions x, y and z axis according to ISO 5349. The orientation of the coordinate system originating in vibrating handle gripped by hand. The evaluation of vibration exposure in accordance with ISO 5349-2001 is based on a quantity that combines all three axes.

Vibration levels transmitted to the drivers hand were measured under two operating condition; idling and full load. Accelerometer was mounted at the steering wheel. Vibration accelerations were recorded in form of frequency-weighted root means square (RMS) accelerations. The results obtained for idling process were, 1.99 m/s^2 for x_h axis, 1.66 m/s^2 for y_h axis, 3.37 m/s^2 for z_h axis and 4.26 m/s^2 in sum axis. Second results were obtained for full load speed process; 3.61m/s^2 for x_h axis, 6.72m/s^2 for y_h axis, 16.20 m/s^2 for z_h axis and 17.91 m/s^2 in sum axis.

Paul Pitts (2004) investigated the hand-arm vibration emission of chainsaw-comparison with vibration exposure. For chain saws the vibration emission values are derived from an ISO Standard test ISO 7505: 1986 “Forestry machinery - Chain saws - Measurement of hand-transmitted vibration”. The declaration for chain saw vibration emission is based on a combination of results from three operating mode: idling, cutting and racing. Five chainsaws were used throughout these studies. They were chosen as being representative of saws of around 50cc capacity. ISO 7505 tests require vibration to be measured at two locations on the saw: on the rear handle and on the top handle. Measurements are made with the saw in three operational modes: idling, cutting (full-load) and racing.

In idling mode the saw is held stationary in the position normally adopted between cuts (i.e. near horizontal). The cutting mode requires a cut to be taken through a specified test log while operating at a specified engine speed that is controlled using the feed force. The racing test is carried out at 133% of full-load speed, with the saw held as for the idling test. Three Brüel & Kjær type 4393 piezoelectric transducers are fitted to a small aluminium mounting-block, which is strapped firmly onto the tool handle using a non-ratchet type nylon cable tie. The vibration data were recorded on a TEAC RD135T 8 channel DAT recorder. Analysis of the vibration data recordings is carried out using a Brüel & Kjær Pulse analysis system. Form the experiment done on 5 different chainsaws, the highest emission recorded from chainsaw A with acceleration value of 8.8m/s^2. The lowest vibration emission was recorded from chainsaw D with acceleration value of 5.4 m/s^2.

Andrew H.Tudor [1996] has carried out a research on hand-transmitted vibration from a curved shaft grass trimmer model *(model brand was not stated)*. The trimmer is powered by a 4-cycle, single cylinder, 23 cc gas engine. The machine weight was recorded at 10.4 pounds with a full gas tank. Full speed during light trimming operation of the subject machine was measured at 8123 R.P.M. vibration measurements were conducted according to ISO 5349-1986(International Organization for Standardization [ISO], 1986). Measurement was taken for various operating modes of the machine.

The accelerometer was mounted on an aluminum mounting block, and the block was clamped to the machine via a hose clamp. A coordinate system relative to the machine's "D" handle was defined in order to report vibration measurements utilizing the basicentric coordinate system. Vibration measurements were taken in accordance with basicsentric coordinate system. A six foot one inch, 190 lb. male performed the actual running of the machine. From the results obtained, the largest recorded single axis, 4-hour equivalent acceleration was 23.94 m/s^2 and occurred at 7846 R.P.M. According to Annex A of IS0 5349 (1986), this level would produce a 10% incidence of finger blanching after 1.25 years. Thus the vibration profile of the subject machine violates Annex A of IS0 5349 (1986).

2.5 Vibration Reduction Technique in Hand Held Power Tools

Manufacturers of hand held power tools have working in ways to reduce vibration originated from the equipment. Example of a road breaker with passive attenuation system is shown in Figure 2.6. A reduction of 90 % of hand arm vibration is claimed. The handles of this tool are spring loaded, with a helical spring mounted cross-wise in the breaker head. In conjunction with the spring, a rubber block comes into play when the tool to extract a stuck chisel.

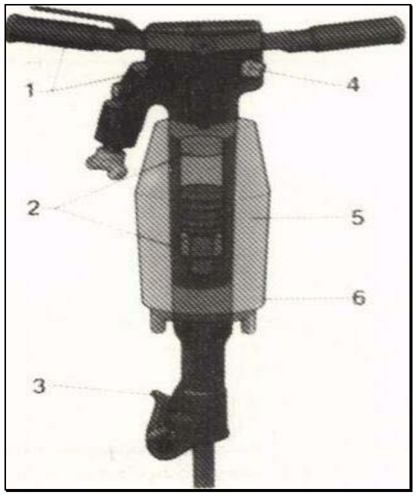

Figure 2.6: Ergonomically design road-breaker

1) Spring suspension.
2) Cushioning behind piston.
3) Latch retainer.
4) Built in lubricator.
5) Silencer reduces exhaust noise by 15 dB.
6) 6-smooth external design.

2.6 Relevant Standards

A number of standards incorporating the latest state of knowledge have been introduced over the last few years with the object of giving guidance to those required to assess the importance of human vibration exposure. For the hand-arm system, the standard is referred to BS 6842 (ISO 5349). The standard specifies general methods for measuring and reporting hand transmitted.

According to the standard, measurements of the vibration should be done as close as possible to the surface which is in contact with the hand **[L.Burstrom et al, 1998]**. It is believed that the most damaging frequency range of vibration is from 8 Hz to 1 kHz, so measurements need to be taken at least between those two frequencies.

Careful selection of the accelerometers and appropriate methods of mounting the accelerometer on the vibrating surface are required to obtain accurate results. Vibration transmitted to the hand should be measured and reported in the appropriate directions of an orthogonal coordinate system (basicentric coordinate) (figure 2.6).

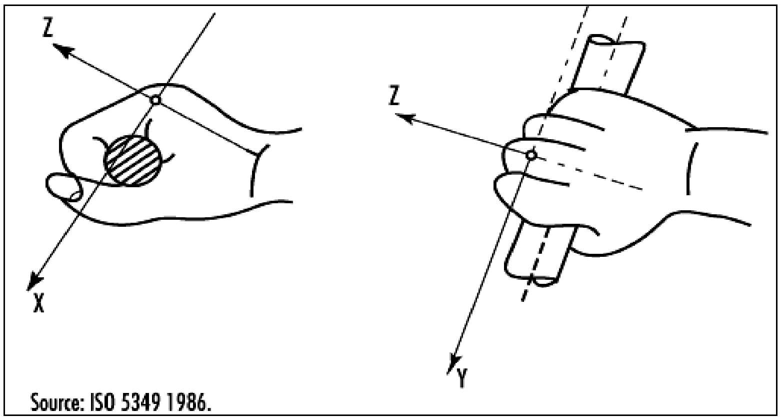

Figure 2.7: Basicentric coordinate system for the measurement of hand-transmitted vibration.

Table 2.2: Axes of vibration

Axis	Hand-Arm Vibration (HAV)
x-axis	Through the hand, from top towards the palm
y-axis	From the right side to the left side, parallel to the knuckles
z-axis	From the wrist through to fingers, parallel to top of the hand

The American Conference of Governmental Industrial Hygienists (ACGIH) recommended daily limits of exposure Threshold Limit Value (TLVs) to frequency weighted acceleration as shown in table 2.3. TLVs for exposure of the hand to vibration in either x_h, y_h, or z_h directions:

Table 2.3: Threshold limit values for hand transmitted vibration **[Proposed OHS Guidelines, 2003]**

Total daily exposure duration	TLV of the dominant, frequency-weighted (rms), component acceleration which shall not be exceeded (ms^{-2})
4 hours and less than 8	4
2 hours and less than 4	6
1 hour and less than 2	8
Less than 1 hour	12

In this case, the value of the frequency-weighted acceleration (x_h, y_h, or z_h) refers to the three perpendicular x-, y-, and z-axes as it applies to the hand. The term dominant means that usually only one axis is dominant. If one or more axes exceed the total daily exposure, then the TLV has been exceeded. **[Proposed OHS Guidelines, 2003]**

BS EN ISO 5349-1(2001) stated that the hand transmitted vibration of a surface or tool can be expressed as a frequency weighted acceleration in m/s^2 ($A_{,hw}$). Measurements are taken in the x,y,and z axes ("triaxial") using accelerometers attached to the vibrating surface. These are combined by the root-sum-of-squares method to give the "vibration total value" (A_{hv}). To allow different exposure patterns to be compared, they are adjusted or 'normalised' to a standard reference period of 8 hours (A(8)) **[http://www.bsi-global.com]**.
Technical considerations sometimes permit measurements in a single axis only (single dominant axis or greatest single axis value).

Physical Agents Directive proposed a daily exposure limit value (ELV) of 5.0 m/s^2 A(8) which means exposure above this limit will not be allowed. If the limit is exceeded immediate action will be required to reduce exposure below the limit and a daily exposure action value (EAV) of 2.5 m/s^2 A(8) which means the workers will be entitled to health surveillance if exposed above this level **[www.occupationalhealth.co.uk/].** These values are based on vibration magnitude obtained from measurements in triaxial directions, with accordance of BS EN ISO 5349-1(2001). Technically these values are greater than single dominant axis, as a solution single dominant axis measurements can be multiplied by 1.4 to convert to triaxial.

Table 2.4: Exposure times equivalent to A(8) of 2.5 m/s^2
[www.occupationalhealth.co.uk/hand_arm_vibration/]

Frequency weighted acceleration of tool (A_{hv}) m/s^2 triaxial	Exposure time to give daily exposure of 2.5 m/s^2 A(8)
16	12 min
12	21 min
8	47 min
6	1 hr 23 min
4	3 hr 8 min
3	5 hr 33 min
2	12 hr 30 min

Table 2.5: Exposure times equivalent to A(8) of 5 m/s^2 **[www.occupationalhealth.co.uk/hand_arm_vibration/]**

Frequency weighted acceleration of tool (A_{hv}) m/s^2 triaxial	Exposure time to give daily exposure of 5 m/s^2 A(8)
16	47 min
12	1 hr 23 min
8	3hr 8 min
6	5 hr 33 min
4	12 hr 30 min

2.6.1 Vibration Exposure Evaluation

The evaluation of vibration exposure in accordance with ISO 5349-2001 is based on a quantity that combines all three axes. This is the vibration total value a_{hv} and it is defined as the root-mean-square of the three component values **[V. Goglia et al., 2003].**

$$a_{hv} = \sqrt{a^2_{hwx} + a^2_{hwy} + a^2_{hwz}}$$

Where a_{hwx}, a_{hwy} and a_{hwz} are the frequency-weighted acceleration values for the single axes.

Vibration exposure depends on the magnitude of the vibration total value and on the duration of the exposure. Daily exposure duration is the total time for which the hand is exposed to vibration during the working day. The daily vibration exposure shall be expressed in terms of the 8-h energy equivalent frequency-weighted vibration total value as:

$$A(8) = a_{hv} \sqrt{\frac{T}{T_o'}}$$

Where T is the total daily duration of the exposure expressed in s to the vibration a_{hv}; and T_0 is the reference duration of 8 h (28 800 s).

The Machinery Safety Directive of the European Community requires that instruction handbooks for hand-held and hand-guided machinery specify the effective acceleration if it exceeds a stated value (2.5 ms^{-2} r.m.s.). Figure 1 shows that according to ISO 5349 (1986), an 8 hour daily exposure to 2.5 ms^{-2} r.m.s would result in 10% of persons with finger blanching after about 8 years and 50% with blanching after about 18 years **[Griffin, 1998].**

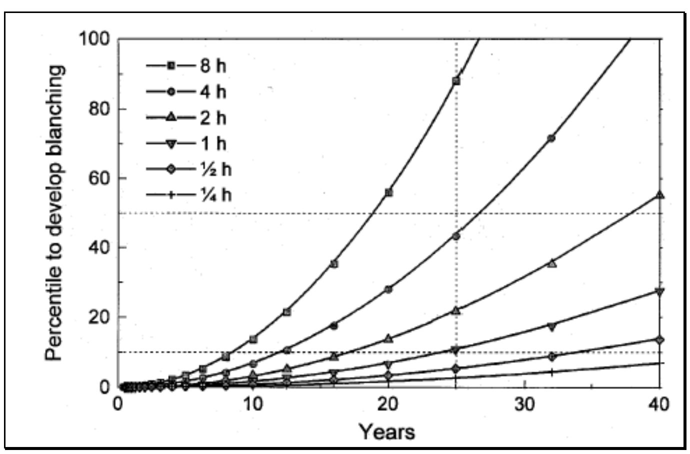

Figure 2.8: Predicted percentile to develop finger blanching at the 2.5 ms^{-2} r.m.s. level defined in the Machinery Safety Directive (calculated from ISO 5349, 1986) **[Griffin, 1998]**.

In developing symptoms such as Vibration White Finger (VWF) the most important factors are the magnitude of the weighted acceleration and the exposure time. Table below shows the likelihood of symptoms developing **[Barber, 1992]**:

Table 2.6: Magnitude of Ah,w (m/s2) which may be expected to produce finger blanching in 10 % of person exposed.

Daily exposure (hours)	Lifetime exposure (Years)					
	0.5	1	2	4	8	16
8	45	22	11	6	3	1
4	64	32	16	8	4	2
2	90	45	22	11	6	3
1	128	64	32	16	8	4
0.5	180	90	45	22	11	6
0.25	256	128	64	32	16	8

The International Organization for Standardization (ISO) has published a method for measuring vibration and interpreting the resulting data. This 1986 standard (ISO 5349) also gives the set of curves shown in Figure 2.9 that can determine exposure levels likely to cause the first signs of white finger in workers.

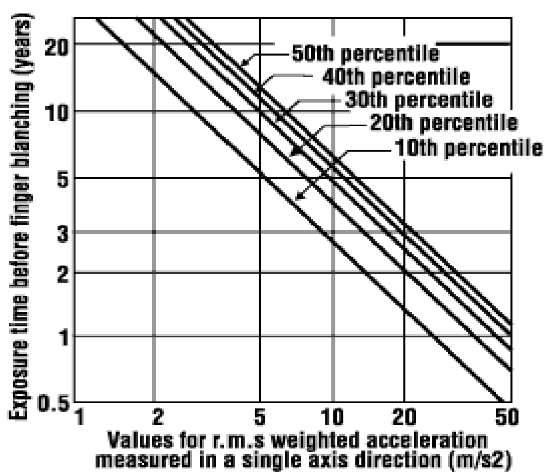

Figure 2.9: Risk of Contracting Vibration White Finger (VWF)
[www.ccohs.ca/oshanswers/phys_agents/vibration/]

Figure 2.10 shows the mean values and range of distribution of frequency-weighted r.m.s. acceleration in the dominant axis measured on the handle(s) of some power tools:

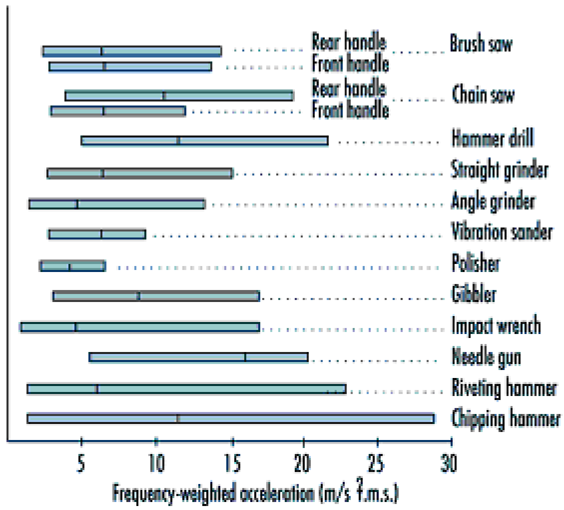

Figure 2.10: Frequency-weighted r.m.s. acceleration in the dominant axis measured on the handle(s) of some power tools **[http://turva.me.tut.fi/]**

2.6.2 Vibration Emission Standard for Chain Saw

Manufacturers and suppliers of hand held power tools, such as chain saws, are required to provide information on hand-arm vibration emission. For chain saws the vibration emission values are derived from an ISO Standard test ISO 7505: 1986 "Forestry machinery - Chain saws- Measurement of hand-transmitted vibration" **[Barber, 1992]**. ISO 7505 tests require vibration to be measured at two locations on the saw: on the rear handle and on the top handle **[Paul Pitts, 2004]**.

CHAPTER 3: METHODOLOGY

3.1 Overview

The first section of this chapter consists of information on the equipments, materials and its utilization. This part explains about particular models of tools used. This consists the function of the particular tools and how it helps in carrying out the experiment. The second section of this chapter is based on the procedures of fabricating the supporting tools. This includes accelerometer mounting device and also the L-shaped thick steel plate as wood log support. The third section of this chapter explains the methods used to measure the vibration. The vibration measurement procedures used during the experiment, the speed measurement procedure and also the process of data compilation will be further explained. The last section of this chapter consists of safety precaution measurements taken during the experiment. This includes the operation of the chainsaw and the precaution step during the cutting operation.

3.2 Experiment Equipment, Material and Its Utilization

3.2.1 The Chainsaw

The chainsaw used in this experiment is from Husqvarna model 340 (model figure shown in chapter 2). This model is a rear-handled chainsaw which consists of main parts such as the engine, guide bar, cutting chain, handle bars, throttle trigger and throttle trigger lockout. This model is categorized in mid-weight chainsaw whereby it is used for frequent log cutting of small to medium diameter trees. The chainsaw is powered by two-stroke engine, which consume petrol as the fuel and lubricant oil for the engine.

Following are the brief specification of the chainsaw used in the experiment:

I. Cylinder displacement – 40.8 cm^3
II. Power – 2.0 kW / 2.7 hp
III. Fuel tank volume – 0.5 liter
IV. Oil tank volume – 0.25 liter
V. Chain pitch – 0.325 inch

3.2.1.1 Starting operation procedure of chainsaw engine:

I. Place the chain saw on level ground in an area free from hard materials.
II. Make sure the bar and chain is up out of the dirt.
III. Make sure the chain saw is turned on.
IV. Set the choke open if its the first starting of the day
V. With one foot placed in the hand guard at the rear of the saw, grip the top handle of the saw firmly with one hand and use the other hand to pull the starting rope.(Figure 3.1)
VI. Rev the chain saw by pressing the throttle by pressing the trigger lockout.
VII. Turn off the engine by pushing down the ON/OFF button.

Figure 3.1: Procedure of Starting the chainsaw

During the engine starting process, some problems might be faced such as difficulties to ignite or start. This could be caused by factors such as, improper starting procedure and spark plug fouled due to contamination at the spark head. To rectify these problems, correct starting procedure had to be followed and the spark plug has to be cleaned.

Before the cutting operation is done few test had been made. The purpose of this test run was to make sure that the subject is getting use to the chain saw. Few cutting operation had been made for testing purpose before the real measurements were taken.

3.2.2 The Wood Logs

Several wood logs had been obtained for the experiment purpose (Figure 3.2). These wood logs used during vibration measurement of cutting operation. The type of logs used in this experiment is ***'setang'*** in Malay which are from softwood category. The size of the logs varies from 19.4 cm to 21.6 in diameter and the length varies from 120 cm to 130 cm.

Softwood type logs had been chosen for the experiment due its ease of cutting. These type woods are easier to be obtained and its sizes are small for ease of handling.

Figure 3.2: Wood log

3.2.3 Integrating Vibration Meter

Integrating vibration meter is used to measure the vibration acceleration from the chainsaw. The type of meter used in the experiment is from Bruel & Kjaer type 2513 (SI Unit) as shown Figure 3.3. The vibration acceleration measurement ranges up 1000 m/s^2. Hand-arm vibration measurement can be done with accordance with ISO 5349. This meter indicates vibration acceleration in true peak, maximum peak, RMS or maximum RMS.

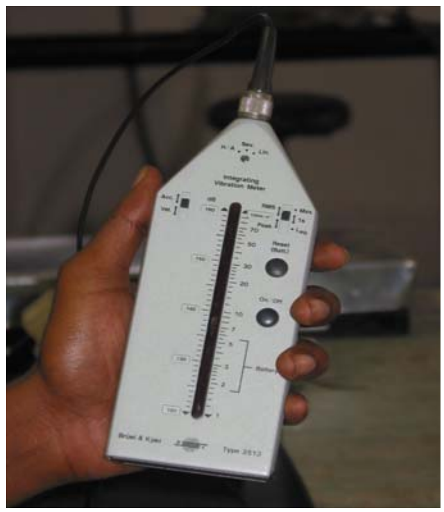

Figure 3.3: Integrating Vibration Meter Type 2513 (SI Unit)

3.2.3.1 Vibration Transducer

A vibration transducer is connected to the vibration meter. This transducer performs as a connector between the meter and the vibrating surface. The transducer used in the experiment is from Type 4834 piezoelectric accelerometer (Figure 3.4). The vibration transducer consists of following elements:

I. Accelerometer Cable AO 0193
II. Adaptor UA 0641
III. Accelerometer Type 4384
IV. Mounting Magnet UA 0642