A STUDY OF VIBRATION REDUCTION BY USING SYNTHETIC MATERIALS

UMARIN TEMEE

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE
(INDUSTRIAL HYGIENE AND SAFETY)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2009**

Thesis
Entitled

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was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Master of Science (Industrial Hygiene and Safety)
on
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ACKNOWLEDGEMENTS

The achievement of this thesis was completed under guidance, reinforcement and kindness of many persons that have to be mentioned and received appreciation from the thesis. I would like to make an acknowledgement speech.

First and foremost, through the many years during which I have been working on this thesis I would like to express my deepest and sincere gratitude to my kind supervisor, Assoc. Prof. Witaya Yoosook, for his expert guidance, strong encouragement, patience, valuable support and advice throughout the development of this study in which enable me to carry out this thesis successfully. He has been a tremendous help to me over the years and has generously spent his time discussing and marking suggestions to improve the thesis.

My appreciation and special thankfulness to my Co-advisor, Assoc. Prof. Pronpimon Kongtip, Asst. Prof. Pramuk Osiri and Assoc. Prof. Vajira Singhakajen for their valuable advice, suggestion, discussions, criticisms and comments. The special thankfulness also extends to Assoc. Prof. Peeti Poonchaisee who was the external examiner for my thesis defense, and who made suggestions and helping me improve this thesis.

Great appreciation would be conferred to Mr.Passapong Natchakannongnapat of Textile Industrial who provided useful information and material field workplace facilities.

I am grateful to all my lecturers; I wish to express my appreciation for their teaching and advice during my graduate studies at Huachiew Chalermprakiet University and Mahidol University.

Finally, I would also like to take this opportunity to express my deepest gratitude and heartfelt appreciation to my lovely family, all relatives and friends for giving me so much support, entirely care, love and understanding which help me to overcome many difficult moments.

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ABSTRACT

The objective of this study was to determine the effectiveness of vibration reduction materials made from synthetic rubber. A rubber belt plate and a rubber valve plate of equal dimensions (360 x 240 x 10 mm) were compared by measuring vibrations from a weaving machine. Vibrations were measured at X and Y axes horizontal and the vertical axis Z at 4 points at the base of the machine. A further 6 point 300 mm. from the edge of the machine were measured for vibrations before and after using the materials. The power was 5HP, 37 kW and 855 rpm.

The physical properties of the rubber belt plate and rubber valve plate were assessed. The rubber belt plate was strong and lasting. It was more abrasive than the rubber valve plate. The rubber valve plate had more ability to support tearing and could return to its previous form after being compressed more than the rubber belt.

The average vibration at the machine along the Z axis was significantly higher than along the X and Y axes before and after using the vibration reduction materials, (p-value < 0.001) but the average vibration along the Z axis was not significantly different when measured before and after using the vibration reduction materials (p-value = 0.650). Average vibration measured at the floor significantly along the Z axis was found to be significantly higher than that for the X and Y axes both before and after the use of vibration reduction materials (p-value < 0.001). Findings from average vibration along the Z axis when measured before and after using the vibration reduction materials revealed significant differences (p-value < 0.001). Also, the vibration at the weaving machine and the floor was found to be significantly different (p-value < 0.001).

The effectiveness in reducing vibration at the weaving machine from the use of rubber belt plate and rubber valve plate was 10.62 % and 16.25 % respectively. The effectiveness of rubber belt plate and rubber valve plate at the floor was 24.45 % and 51.18 %, respectively; this means that the rubber valve plate was more effective in vibration reduction than rubber belt plate.

This study indicates that synthetic rubber materials which have flexibility and suitable properties can be adapted for use as materials to reduce vibration from machines transmitting vibrations to the floor.

KEY WORDS: VIBRATION / VIBRATION REDUCTION MATERIALS / STNTHETIC MATERIALS / WEAVING MACHINE

125 pp.

ศึกษาการลดความสั่นสะเทือนโดยใช้วัสดุสังเคราะห์ที่ผ่านการใช้งานมาแล้ว
(A STUDY OF VIBRATION REDUCTION BY USING SYNTHETIC MATERIALS)

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บทคัดย่อ

การศึกษาครั้งนี้มีวัตถุประสงค์ในการทดลองเพื่อศึกษาประสิทธิภาพของวัสดุลดความสั่นสะเทือนที่ทำจากยางสังเคราะห์ คือ แผ่นสายพานลำเลียงและแผ่นวาล์วยางมีขนาด 360 x 240 x 10 mm ทำการวัดค่าความสั่นสะเทือนทั้ง 3 แกน คือ แกน X, Y และ Z 4 จุด ที่ฐานเครื่องทอผ้าที่มอเตอร์มีกำลัง 5 แรงม้า 37 กิโลวัต และความเร็วรอบ 855 รอบต่อนาที และ 6 จุด บริเวณพื้นริมเครื่องทอผ้า ซึ่งจะทำการตรวจวัดค่าความสั่นสะเทือนทั้งก่อนและหลังการใช้วัสดุลดความสั่นสะเทือน

เมื่อพิจารณาคุณสมบัติทางด้านกายภาพของแผ่นสายพานลำเลียงและแผ่นวาล์วยาง พบว่าแผ่นสายพานลำเลียงมีความแข็งและมีความคงทนต่อการสึกหรอมากกว่าแผ่นวาล์วยาง แผ่นวาล์วยางสามารถรับแรงดึงและมีแรงคืนตัวเมื่อถูกกดทับได้มากกว่าแผ่นสายพานลำเลียง

ผลการศึกษาความสั่นสะเทือนที่วัดได้จากเครื่องทอผ้าพบว่าค่าเฉลี่ยความสั่นสะเทือนในแกน Z มีค่าสูงกว่าแกน X และ แกน Y ทั้งก่อนและหลังใช้วัสดุลดความสั่นสะเทือน มีความแตกต่างกันอย่างมีนัยสำคัญ (p-value < 0.001) แต่กลับพบว่าค่าเฉลี่ยความสั่นสะเทือนในแกน Z ก่อนและหลังการใช้วัสดุลดความสั่นสะเทือนมีค่าไม่แตกต่างกัน (p-value = 0.650) และผลการศึกษาความสั่นสะเทือนที่วัดได้จากพื้นพบว่า ค่าเฉลี่ยความสั่นสะเทือนในแกน Z มีค่าสูงกว่าแกน X และแกน Y ทั้งก่อนและหลังใช้วัสดุลดความสั่นสะเทือน มีความแตกต่างกันอย่างมีนัยสำคัญ (p-value < 0.001) และเมื่อพิจารณาค่าเฉลี่ยความสั่นสะเทือนในแกน Z พบว่า ค่าเฉลี่ยความสั่นสะเทือนก่อนและหลังใช้วัสดุลดความสั่นสะเทือน มีค่าแตกต่างกันอย่างมีนัยสำคัญ (p-value < 0.001) นอกจากนี้ยังพบว่าค่าความสั่นสะเทือนที่เครื่องทอผ้ากับพื้นมีความแตกต่างกันอย่างมีนัยสำคัญ (p-value < 0.001)

ประสิทธิภาพในการลดความสั่นสะเทือนของสายพานลำเลียงและแผ่นวาล์วยางที่เครื่องทอผ้ามีค่าร้อยละ 10.62 และร้อยละ 16.25 ส่วนประสิทธิภาพในการลดความสั่นสะเทือนของสายพานลำเลียงและแผ่นวาล์วยางที่พื้นมีค่าร้อยละ 24.45 และร้อยละ 51.18 ตามลำดับ ซึ่งแสดงให้เห็นว่าแผ่นวาล์วยางมีประสิทธิภาพในการลดความสั่นสะเทือนได้ดีกว่าสายพานลำเลียง

ดังนั้นจึงสรุปได้ว่า วัสดุที่ทำจากยางสังเคราะห์ซึ่งมีคุณสมบัติความยืดหยุ่นและมีคุณสมบัติทางกายภาพที่เหมาะสมสามารถนำมาประยุกต์ใช้เป็นวัสดุลดการส่งผ่านความสั่นสะเทือนจากเครื่องจักรได้

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CHAPTER I
INTRODUCTION

1.1 Background and Rationale

Industrial development has certain role in the country development as being seen from the developed country mostly with advance industrial development. Thailand is one of the countries aiming actively at the industrial development. An industry which considered crucial for the country's development is the Textile Industry. There are has many textile factories consisted of small garment factories in Thailand. The current statistic from Industrial Factory Information Center, Industrial Factory Department, Ministry of Industry indicated that in the year 2005, the factories received the permits to operate were 1,320 factories with 116,040 workers. In Asia Pacific, Textile Industry has contributed about 70 percent of worldwide products which resulted in occupational hygiene and safety among workers in the industry of developed country. This is the important topic which needed more attention.

In developing these industries, the workers come in contact more with the risk factors and the critical risk factor in the Textile industry is vibration from operating the machines during the production process. Vibration can cause harm to workers' bodies when touching vibrated machine, causing discomfort feelings, exhaustions, and injuries as well as reducing work efficiency. Moreover, vibration can damage building structure and making it unstable and later unsafe.

Many studies were done on the effect of vibration at specific place and finding ways to control danger from vibration. Only few studies were done on the danger of whole-body vibration towards the body working system. The following studies are available:

Kubo and Associates (1) studied the association between touching whole-body contact and heartbeat rate, blood pressure and breathing. Findings indicated that

Whole-body vibration had influenced human physiology such as heartbeat rate, blood pressure and breathing.

Griffin (2) studied the association between size and frequency of vibration and exhaustion among vehicle drivers. The result revealed that vibration from driving can cause exhaustion. Leu and Associates (3) studied unfit environmental factors effecting human body among the persons exposed to vibration from vehicles such as automobiles, buses, trains, boats, and airplanes, findings shaved that vibration was the cause of discomfort feelings, exhaustions and injuries.

Another way to control and prevent the danger from whole-body vibration, the vibration could be reduced by using supporting material, eq. cloth, plastic and rubber. However, it requires the huge budget. The reports from above-mentioned studies revealed the effect and danger from vibration. Therefore, the researcher was interested in the study of effectiveness in the use of vibration reduction materials to support the machine base in order to reduce vibration transmitted from the machine to the workers.

1.2 General Objective

To study effectiveness of vibration reduction materials to support machine base in the Textile Factory.

1.3 Specific Objectives

1.3.1 To compare the vibration of machine before and after the use of vibration reduction materials to support the machine base.

1.3.2 To compare effectiveness reduction of the vibration machine with 2 types of materials used for supporting the machine base, namely used the rubber belt plate and the rubber value plate

1.3.3 To compare the vibration at floor before and after the use of vibration reduction materials to support the machine base.

1.3.4 To compare effectiveness reduction at floor with 2 types of materials used for supporting the machine base, namely used the rubber belt plate and the rubber value plate.

1.4 Hypothesis

1.4.1 The vibration values at machine in each point before and after using the rubber belt plate and the rubber valve plate should be not different.

1.4.2 The vibration values at machine in each axis before and after using the rubber belt plate and the rubber valve plate should be different.

1.4.3 The vibration values at machine before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration in Z axis should be different.

1.4.4 The vibration values at floor in each point before and after using the rubber belt plate and the rubber valve plate should be not different.

1.4.5 The vibration values at floor in each axis before and after using the rubber belt plate and the rubber valve plate should be different.

1.4.6 The vibration values at floor before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration in Z axis should be different.

1.4.7 The vibration values at machine and floor before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration in Z axis should be different.

1.5 Variables

1.5.1 Independent Variables such as:

1.5.1.1 Materials used for reducing vibration at the machine base such as used the rubber belt plate and used the rubber valve plate.

1.5.2 Dependent Variables

1.5.2.1 The vibration values at weaving machine

1.5.2.2 The vibration values at floor

1.5.3 Observed Variables

1.5.3.1 Work Nature

1.5.3.2 Machine at work

1.5.3.3 Physical property of vibration reduction materials

1.5.3.4 Measurement point of vibration

1.6 Scope of the Study

This study has the following scopes for testing samples:

1.6.1 Making the comparison of vibration machine and floor before and after the use of vibration reduction materials

1.6.2 Making the comparison of vibration machine and floor from the use of both types of vibration reduction materials

1.6.3 Vibration reduction materials in this study were used the rubber belt plate and used the rubber valve plate.

1.6.4 This study tested vibration resulted from the weaving machine. TOYOTA, Model JAT710 Air Jet, power 5 HP, 37 kW and 855 rpm.

1.6.5 This study tested vibration resulted from only one weaving machine.

1.6.6 This study is testing vibration originated at Z axis as the only axis in the experiment.

1.6.7 Using the RMS of aceleration to measure volume of vibration

1.6.8 m/s^2 is the measure unit of vibration

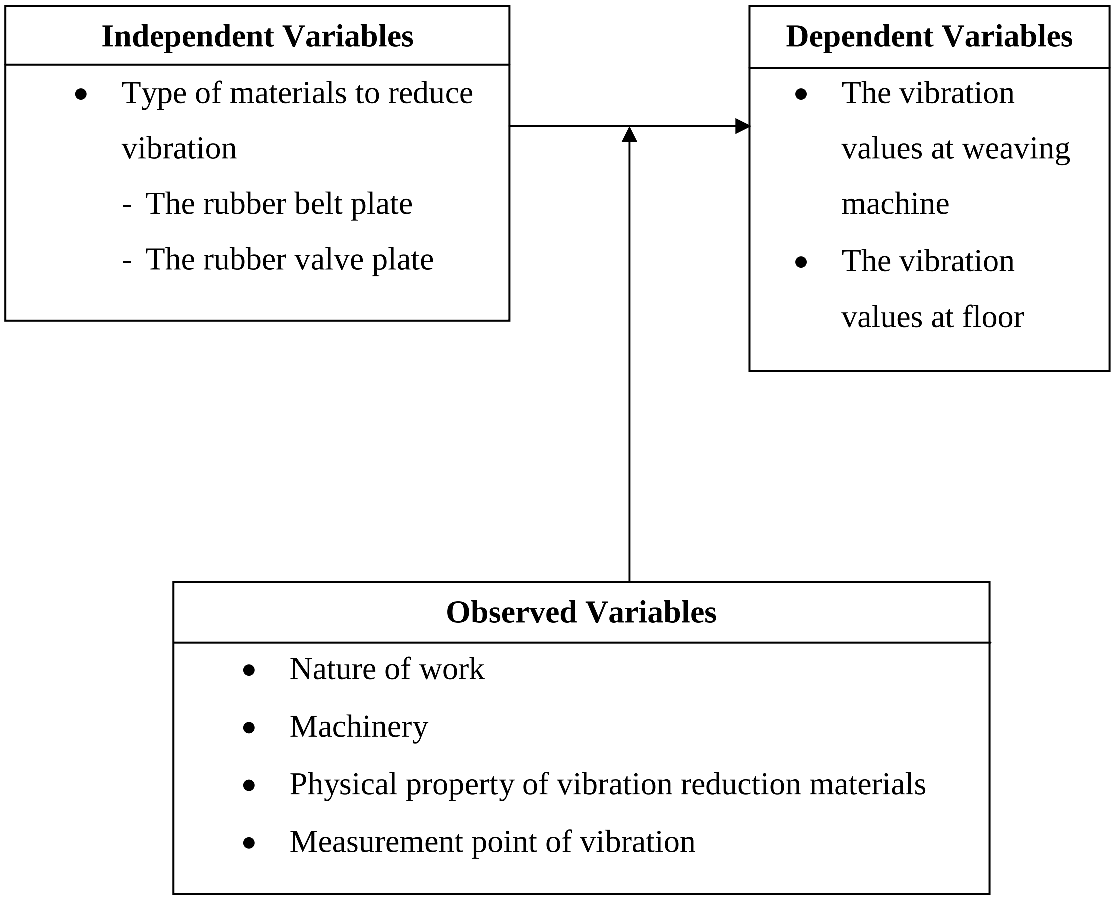
1.7 Outcomes

Research results could be adapted for using the supporting materials to reduce machine vibration transmitted to employee’s body.

1.8 Expected Benefits

Supporting material can be used for decreasing vibration from weaving machine to the worker in order to reduce danger from vibration.

1.9 Conceptual Framework



1.10 Definitions

Vibration	Mechanical energy that made the objects moved from the axis. Because of the influence of Inertia, Elastic and Friction of the objects towards the environment outcomes of vibration would have different properties.
Vibration Meter	A tool for measuring acceleration and velocity of vibration.
Vibration Reduction Materials	Materials used for reducing vibration from machine to human.
Synthetic Materials	Materials that have been manufactured or otherwise created by human beings, as opposed to those occurring in nature.
Textile Industry	Spinning, weaving and decoration as combination of arranging fiber for threads, spinning threads, weaving, printing fabric, bleaching, dyeing and decorating threads or fabrics.
Floor	The floor near by the weaving machine where taken measurement vibration.
Exhaustion	It is the combination of both spirit and body together that usually happened after heavy exercise or excess use of brain.

Frequency	Number of vibration per unit of time with the use of international frequency scale of Hertz = Hz or round per minute. In some case, it may be expressed as number of a round, 1 hertz = 60 rounds per minute.
Direction	Vibration moved from 3 axes X, Y and Z. Measuring vibration along Z axis is defined as measuring vibration perpendicular to the floor passing the body longitudinal from feet to head. Measuring vibration along X axis is defined as measuring vibration parallel to the floor passing from front to back. Measuring vibration along Y axis is defined as measuring vibration parallel to the floor passing body from the side.
Tensile strength	It is the maximum tensile that the testing piece can tolerate before breaking during the experiment.
Compression set	Testing rubber ability to maintain elasticity after receiving the pressure for certain period based on ISO 815 and 1653 for testing standard. Testing results were percent of compression period for rubber unable to return to previous form as compared to compression distance.
Hardness	Surface resistance towards penetration of specific indenter and under defined compression for testing Durometer, having Shore unit (ASTM D 2240) or IRHD with stiffness as IRHD (ISO 48).

CHAPTER II
LITERATURE REVIEW

2.1 Vibration (2)

Vibration was the mechanical energy to move the object from the center axis. Because of the influence from Inertia, Elastic and Friction towards the environment and stimulated energy, outcomes from vibration had different properties.

Vibration resulted from machines, tools and other equipment might happen both longitudinal and lateral. The source of vibration came from the tractors, trucks, street drilling, and electrical saw. Such tools might be used in agriculture, construction, transportation, and forestry, mining and general industry. There were many workers exposed to vibration. Findings indicated that it might cause health problems among the machine users. In some cases, vibration might be the cause of accident.

When human body exposed to vibration, it would response immediately. Easy explanation, it was based on the same principle of vibration in the medium. Imagine human body was one type of medium, after receiving vibration converting into energy, the molecules inside the cells or tissues would shake or move, which caused unbalance in the object molecule or cells tissues or muscles inside the body making it to shake. Severe shaking could cause exhaustion or fatigue. For example, when a person stood on the vibrated wood panel, vibration would travel into the body passing through feet and then the body, stomach, spinal cord then to arms, shoulders and head. For low vibration, a person might feel on the lower part such as legs, more vibration, feeling occurred throughout the body. For the body part which directly exposed or was close to the source at the origin of the vibration tended to have more response which make that organ exhausted, perhaps more than other parts of the body.

2.2 Type of vibration (2,4)

Vibration was the movement of material under force which might be internal or external force. There were 2 types of vibration as following.

1. Free vibration was a movement of mass in the system of internal force without external force
2. Forced vibration was a movement of mass in the system of external force, this vibration was happened according to the characteristic of external force and frequency of force stimulated the system.

2.3 Vibration Characteristic (4,5)

Vibration is characterized by intensity, frequency, duration and direction.

2.3.1 Intensity

The intensity of vibration was generally described by acceleration, which was normally expressed in terms of meters per second squared (m/s^2). The magnitude of vibration is expressed as a root mean square (rms) value. When the peak values are measured, these are converted as appropriate to rms values before comparing with the limits given in ISO 2631.

2.3.2 Frequency

The frequency of vibration was expressed in cycle per second (hertz, Hz) affected the extent of vibration transmitted to the body (e.g., to the surface of the seat or the handle of vibratory tools), the extent to which it was transmitted through the body (e.g., from the seat to the head), and the effect of vibration in the body. The relationship between the displacement and the acceleration of a motion was also depended on the frequency of oscillation at the low frequencies but a very high acceleration at high frequency; the vibration displacement visible to the human eye did not provide a good indication of vibration acceleration.

The frequency of vibration could be show in the spectra for many types of whole-body and hand-transmitted vibration, the specters are complex, with some motion occurring at all frequencies. Nevertheless, there were often peaks, which show the frequencies at which most of the vibration occurs.

Since human respond to vibration vary according to the vibration frequency, it is necessary to weight the measured vibration according to how much vibration occurs at each frequency. Frequency weightings reflect the extent to which vibration cause the undesired effect at each frequency. Weights are required for each axis of vibration. Different frequency weightings are required for whole-body, hand-transmitted vibration.

2.3.3 Duration

Human responded to vibration increases with increasing the duration of exposure, so it is important to define measured which incorporate the exposure time factor. To determine the effective daily exposure duration, it is necessary to gather information on the number of minutes or hours per day when the exposure to vibration occurs, then the number of weeks or months per year during which work involving vibration is carried out.

2.3.4 Direction

The exposure of the human body to vibration is assessed by measuring vibration entering the body. The vibration is normally measured along three perpendicular directions (Ex. Longitudinal, Lateral or Transverse and Rotation). If there is more than one point at which vibration enters the body, there will be more than one co-ordinate system for obtaining measurements.

2.4 Object response to vibration energy (2,4)

When the object is being stimulated with vibration, such object would respond in 3 ways as follows:

1. Displacement: Of the object is vibrated along with stimulated energy in order to release energy. Vibration may be different from the source. It depends an it's as a result of own Inertia, Elastic and Friction and also Friction from touching nearby objects, When its wave is higher than the wave of the source (Caused of Resonance if the stimulated energy is the same as the object Natural frequency) and perhaps its wave is layer (Caused damping if there is more friction or resistance)

2. Changing into the medium of energy propagation if vibration comes from the source of suitable frequency with 3 properties of the object.

3. Dissipation; from vibration energy transformed into heat energy. When the object cannot transfer energy as vibration, the object may be harmed from existing heat.

2.5 Types of experience in vibration (2,4)

There are two classifications for vibration exposure:

2.5.1 Whole-body Vibration

It is vibration passing from the floor or worker's body structure such as vibration from the floor to the worker's body while standing and vibration passing through the seat of the forklift, tractor and truck drivers and crane operator.

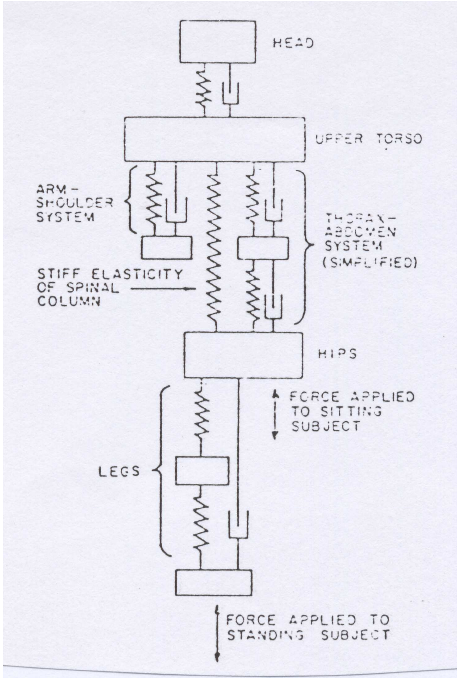


Figure 2-1 Duplication of whole-body vibration

2.5.2 Hand-arm Vibration

It is vibration passing through the tools or equipment to the worker's organ, mainly hands, fingers and arms. Danger happened from vibration, especially on certain part of the body is different from whole-body vibration because danger is happened on the specific especially on fingers and hands which touch and handle vibration tools or equipment organ such as electric saw, air pumped hammer, pegging machine and stone drill. Prolong use of these tools can cause the abnormality in workers or users bodies.

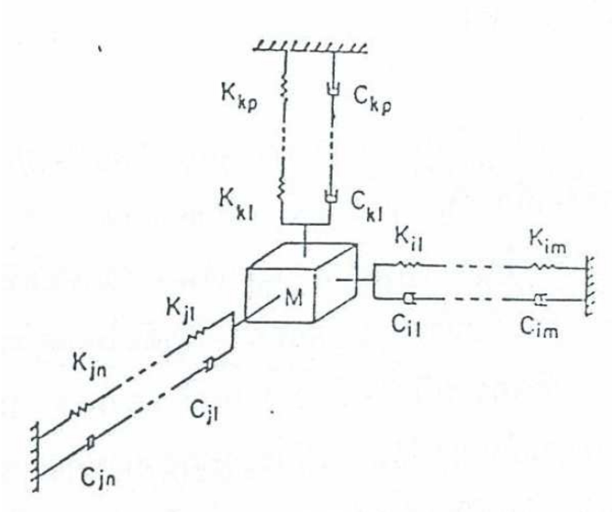


Figure 2-2 Duplication of hand vibration

2.6 Whole-body Vibration (2,4)

An occurrence of Whole-body vibration is induced by mechanical energy which comprise of velocity as root-mean-square (RMS) and duration. In these conditions, most workers may be an exposed to a risk to get low back pain. Picture presents Biodynamic coordination system of each axis of body.

The occupation which taking a risk to expose to the dangers of whole-body vibration comprise of the truck, bus, tractor and forklift drivers, heave tool or equipment or machine operators, train, and crane operator, weavers, steel and cold mine operator and shoes maker .

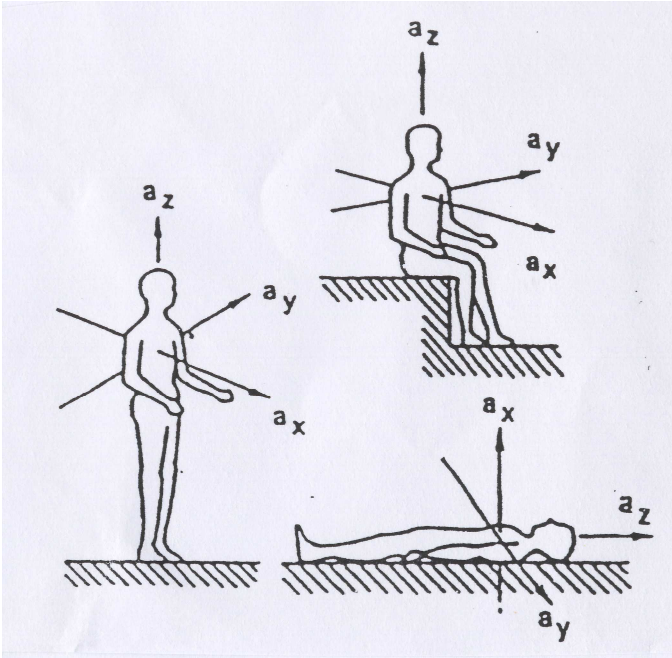


Figure 2-3 Measuring Acceleration in the Biodynamic coordination system (adapted from ISO 2531 ax, ay, az = acceleration in axis x, y and z, axis x = back-chest y= left-right, z= feet-head)

2.7 Abnormality of Body Functions caused by Vibration (6,7)

Since human body consisted of organs with different physical properties in Inertia towards movement and elastic or property to maintain shape and size, including the friction of related organs and natural frequency of own organs. Any abnormality of internal organs caused by vibration depends on the specific property of such organ causing the response in the following forms:

1. Resonance: Each type of materials has own natural frequency which may cause the balance between Inertia and Elastic of such object which could be vibration non-stop under no resistance conditions. Therefore, when vibration energy contacts the body in the same frequency as Natural frequency, resonance could be occurred which caused the same vibration frequency as natural frequency of the organ. Then, such organ should move far away from the normal position and tear the tissue connected with that organs and even causing direct harm to that organ.

2. Damping which happened between the organs makes vibration energy transmit from the target organ to the nearby organ, leading to reducing harm to the target organ. This phenomenon is called Damping. As a result of this damping, such organ would be vibrated along with the nearby organ as if being the medium of energy propagation.

2.8 Effects Factors of Transmitted Vibration (2,6)

Effect of vibration energy as was depended on the property of such body and vibration energy. The severity of the effect is concerned the following factor:

2.8.1 Factor of body

- Natural frequency of the effected organs & Resonance.
- The strength of tissue.
- The posture of the body and activity position during exposure.
- Muscular tone.

2.8.2 Factor of vibration and Environment

- Degree of displacement or amplitude & Acceleration.
- The duration of exposure per working day. In the frequency interval between 1-50 Hz, the whole body would be shaking and such body would be the medium of energy propagation in light frequency interval.
- The frequency spectrum of vibration
- Direction absorbability of material characteristics to expose between the body and energy.

2.9 Health hazard from experiencing whole-body vibration (8,9,10)

Vibration effects on ability of sight lead to poor vision. The internal organ would be harmed if the body repeatedly exposed the high frequency of vibration. The workers who operate heavy equipment often experience vibration. The effect of vibration on the human body is classified as 3 boundaries.

1. Comfort boundary is the level of vibration which the body can expose in the limited time. High vibration would reduce comfort feeling.

2. Fatigue bounding is the level of vibration which cause fatigue and reduce efficiency of control.

3. Exposure bounding is the level of vibration which harms the human body. Vertical vibration would effect on the head. Most people can receive vibration in the frequency interval between 4-8 Hz but they can absorb vibration in the frequency interval between 1-2 Hz in the laterals direction.

Whole-body Vibration caused health hazard among workers in the industrial sector usually in the frequency interval between 0.1-20 Hz because the frequency higher than this usually is damped by the materials across the body and energy. Vibration which could be harmful to health is depended on intensity, exposure duration and direction.

2.9.1 Motion Sickness and Disequilibrium

Motion sickness is temporary abnormality because Vestibular apparatus's function has been disturbed, causing the control organ to sending nerve current to the central nervous system to stimulate the Vomiting center at Medulla, making the patient feel dizzy, vomit and lose appetite. Motion sickness usually found among the persons who received low frequency vibration between 1-1 Hz longitudinal such as vibration from waves or vehicles running on the gravel road.

2.9.2 Poor Visions

It is the temporary symptom caused by vibration during the frequency over 2 Hz which lead to eyes' muscle function abnormally and lack of ability to detect object's movement clearly.

2.9.3 Danger to blood circulation, heart and blood vessels

Vibration with the frequency interval between 2-20 Hz with the intensity about 0.1-1 g lead to the pulse moving faster and increase of Cardiac output and blood pressure. Furthermore, there were the reports among the truck drivers exposed to vibration between 3-10 Hz causing dizziness from reducing the amount of blood circulated to the brain and cases causing hemorrhoids in some cases.

2.9.4 Danger to Respiratory System

Increasing the rate of breathing caused Hyperventilation, oxygen glutting in the blood stream and lower amount of carbon dioxide, leading to Respiratory alkalosis and shrinking blood vessels at the tip so patient would experience eyes blurry and numbness at the tip of fingers and feet.

2.9.5 Danger to Orientation System

The coordination of brain and central nervous system controlling sense of body, eyes and ears identity the position of body and touching object. Since the body, received vibration at the frequency about 2Hz for a period of time, the coordination of the system was damaged leading to tempos loss of ability to identify the actual position of the body and the object.

2.9.6 Danger to Nervous System, Muscles and Bones

High frequency in the range of 10 Hz to 200 Hz Vibration caused muscle strain and contraction as well as reducing Deep tendon reflex, leading to backbone deformation from receiving vibration for extended duration.

2.9.7 Danger to Internal Organ

If the frequency of vibration matched with Natural frequency of internal organs, resonance may cause them to swollen and bruise.

2.9.8 Easily Tired and Irritable

Receiving excess vibration would cause discomfort feeling and easily irritated.

2.9.9 Vibration sickness

It is the total symptoms of the of workers who have experienced vibration for extended duration, causing irregularity of digestive system such as wound in the stomach and irregular bowel movement, degenerative vision and Labyrinth dysfunction together with muscles strain.

2.10 Measurement of Vibration (7)

2.10.1 Value of vibration quantity measurement

1. Peak value is maximum value of function e.g.: Peak value of displacement.
2. Average value is average of time.
3. Root Mean Square value (RMS) is square root of average value square.

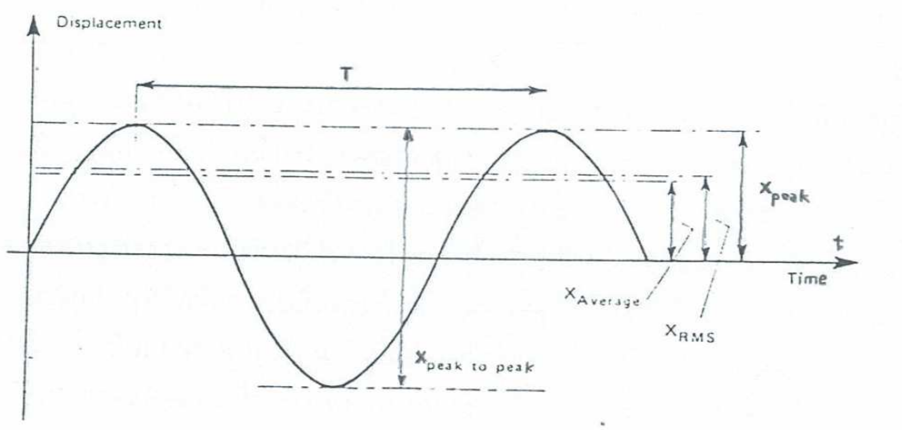


Figure 2-4 Averages and Maximum of Vibration Value

2.10.2 Parameter

1. Displacement is a value of distance from a starting point (in mm).
2. Velocity is a value of distance change to be related with duration (in m/s^2).
3. Acceleration is a rate of velocity change per duration (in g).

Displacement is a figure with material strain. A measurement of displacement useable at the low frequency. In high frequency displacement will decline and unclear. Normal machines with the high speed displacement will have low value and unclear then used velocity is another parameter for vibration measurement because the frequency at 1 kHz will the generate smooth frequency vibration. If the higher frequency is than 1 kHz, the parameter should be acceleration because the displacement and velocity will be dropped quickly in the high frequency.

2.10.3 Relationship between acceleration, velocity and displacement

Considering graph figure showing displacement relationship as Sine wave for easiest movement as Harmonic motion as shown in figure 2-5. Findings from the study indicated that displacement, velocity and acceleration related to each other. Then, knowing one value can reveal another one value as well.

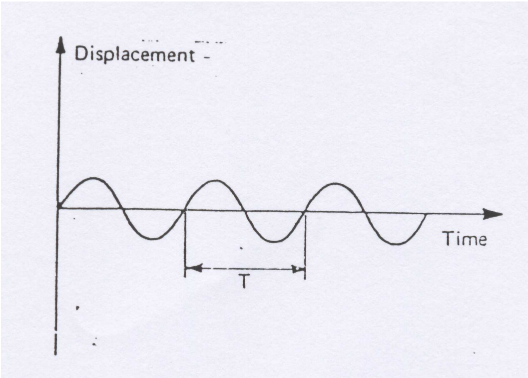


Figure 2-5 Sine wave (f= 1/T)

Formula to reveal association of all 3 values:

$$a = 2fv$$

$$a = (2 ¶f)^2 d$$

Given a = acceleration (g)

v = velocity (m/s^2)

d = displacement (mm)

¶ = 3.141

f = frequency (Hz)

2.10.4 Components of vibration measured instrument

The instrument used for measuring vibration should contain the following components, mainly in 3 major parts, transducer, preamplifier and recorder. More components are as follows:

- Transducer is the head to measure vibration with many types based on principles by changing vibration energy from mechanic energy into electrical energy before measurement. The most popular transducer is Piezoelectronic.

- Preamplifier is signal increment from transducer enough for expansion.

- Integrator is changing the measured unit from transducer as Velocity and Displacement.

- Amplifier has two important functions, as the connector and signal adaptor from transducer. Even increasing with signal expansion by preamplifier, it is not enough to display results. This is the step to enlarge signal.

- Overload indicator is to prevent signal distortion from excessive signal transmission when expanding circuit.

- Detector acts as signal measurement in various forms such as RMS Peak or average to display results on Monitor.

- Furthermore, there are many devices to assist main instrument for more effective measure meant such as Turntable filters and Graphic-recorders.

2.11 Vibration measurement and evaluation methods (11,12)

2.11.1 ISO 2631 : 1997(E)

Mechanical vibration and shock-evaluation of human exposure to whole-body vibration to define methods for measurement of periodic, random and transient whole-body vibration. Applicable to vibration in the frequency rang of 0.5 Hz to 80 Hz for health, comfort and perception (previous stand rms: 1.0 Hz to 80 Hz). This standard includes informative annexes that indicate current opinion and provide guidance on the possible effects of vibration on health:

- Based mostly on Z-axis research of seated and stand persons.

- Limited X and Y axis experience incorporated.

- In case of very low frequency and low vibration magnitudes, e.g. in buildings or ships, velocity measurements may be made and translated in to accelerations.

- Transducers shall be located so as to indicate the vibration at the interface between the human body and the source of its vibration.

- Vibration shall be measured according to a coordinate system originating at a point from which vibration is considered to enter the human body.

- For the comfort and the perception of standing and recumbent persons guidance is provided for periodic, random and transient vibration occurring in the there the weighted r.m.s. acceleration shall be determined for each axis (x, y and z) of translational vibration on the surface which supports the person.

2.11.2 ISO 10816 : 1997(E)

The standards for measurement and assessment of machine vibration in accordance with ISO 10816 in part 1, general specification can be concluded as follows:

Measurement parameters are as follows:

1.) Frequency range for selecting frequency in the measurement depended on the machine type by choosing frequency to match with machine frequency.

2.) Measurement quantity is used for Vibration displacement in micrometer, and Vibration velocity in mm/s and Vibration acceleration in m/s^2.

3.) Vibration magnitude

4.) Vibration severity

Measuring positions to measure machine vibration should be done at the area responded to Dynamic forces and vibration patterns of all machines. Vertical or horizontal measurement must be done when all 3 axes are at perpendicular positions in the same direction during the measurement process.

Measuring machine vibration must be done while the machine is working normally. If the measured vibration appeared higher than determined values, vibration of the surrounding environment must be measured also by measuring while the machine stopped working.

Vibratory waveform relationships is shown in figure 2-6

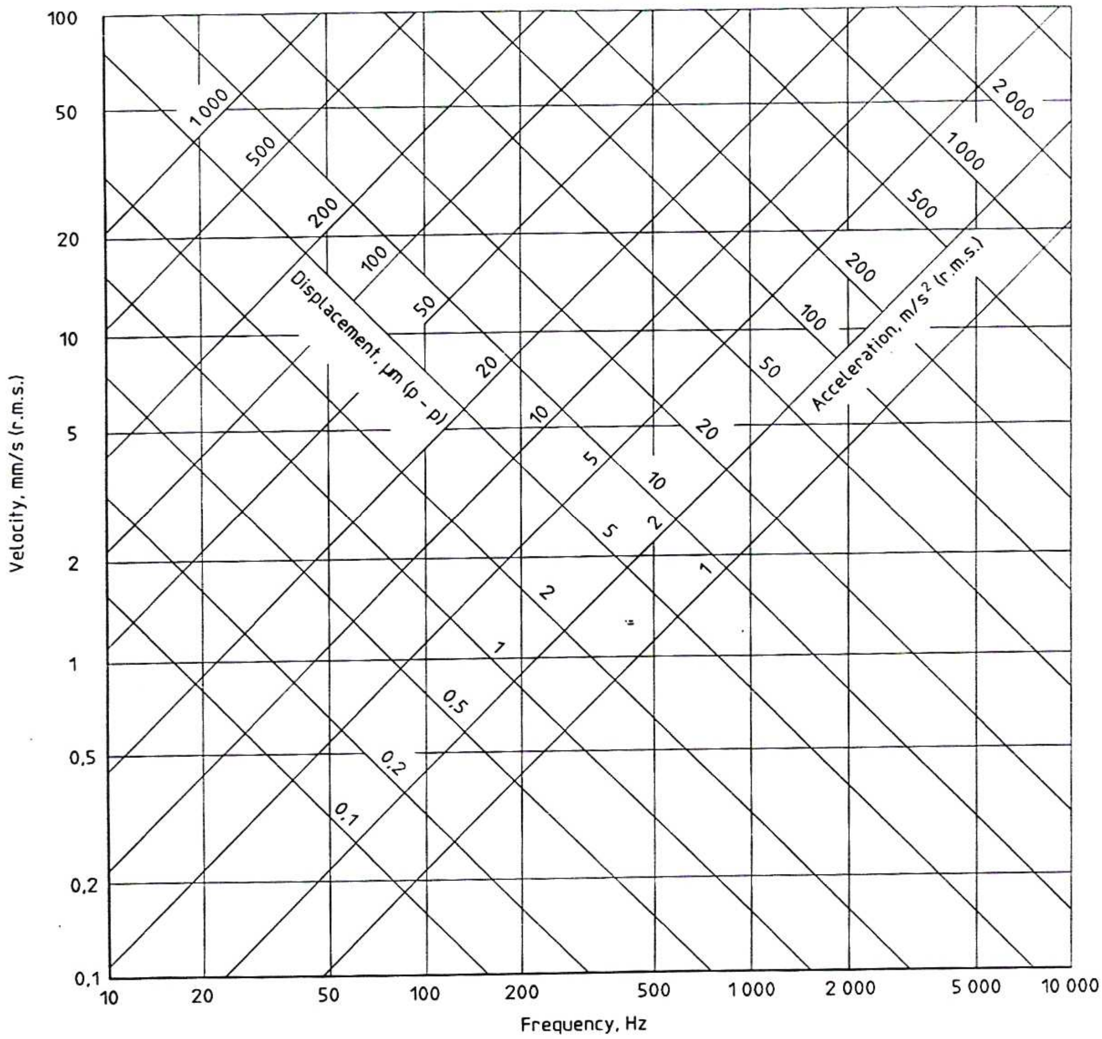


Figure 2-6 Relationship between acceleration, velocity and displacement for single-frequency harmonic components

Evaluation criteria

There are 2 criteria for evaluation.

1.) Criterion I: Vibration magnitude

It is related to determining Vibration magnitude which allows Bearing to take over the Dynamic load, transmit vibration to the Support Structure and Foundation of the machine.

Maximum vibration magnitude doe determining areas are evaluated in 4 areas:

Zone A: New or modern machines

Zone B: Machine without lifetime limitation

Zone C: Machine with lifetime limitation which requires the repair after using for certain period

Zone D: Vibration with potential damage to the machine

2.) Criterion II: Change in vibration magnitude

Criteria II is related to change in the magnitude of machine vibration under normal working conditions by measuring vibration to compare Transducer location and orientation. Any changes in the magnitude out of ordinary must be investigated immediately to avoid danger.

Table 2-1 Typical zone boundary limits

<table>
<tr><th>R.m.s. vibration velocity
mm/s</th><th>Class I</th><th>Class II</th><th>Class III</th><th>Class IV</th></tr>
<tr><td>0,28</td><td rowspan="3">A</td><td rowspan="4">A</td><td rowspan="5">A</td><td rowspan="6">A</td></tr>
<tr><td>0,45</td></tr>
<tr><td>0,71</td></tr>
<tr><td>1,12</td><td rowspan="2">B</td></tr>
<tr><td>1,8</td><td rowspan="2">B</td></tr>
<tr><td>2,8</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>4,5</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>7,1</td><td rowspan="5">D</td><td rowspan="2">C</td></tr>
<tr><td>11,2</td><td rowspan="4">D</td><td rowspan="2">C</td></tr>
<tr><td>18</td><td rowspan="3">D</td></tr>
<tr><td>28</td><td rowspan="2">D</td></tr>
<tr><td>45</td></tr>
</table>

Table 2-1 Four Classes of machines

Class I: Engine and machine joined together as one while working normally (motor power up to 14 kW).

Class II: Medium size machine (Motor power 15kw to 75 kW) has no specific pattern, no elasticity or machine with specific installment (up to 300 kW).

Class III: Driving force for machine is big and large size machine with rotating masses mounted on rigid and heavy foundations which are relatively stiff in the direction of vibration measurements.

Class IV: Driving force for machine is big and large size machine with rotating masses mounted on foundations which are relatively soft in the direction of vibration measurements.

2.12 Standard of Vibration (6,11,13)

At present there is no any appropriate standard for safety because of variety in nature of work and individual. International Standards Organization (ISO) recommended working procedures related to vibration received by the workers by considering 4 major components including: force of vibration, frequency of vibration, direction of vibration and duration of vibration.

In measuring vibration, measuring at each point is the measurement in 3 direction set perpendicular continuously by expressing as RMS of acceleration. For each axis, analysis must be done to separate frequency in the interval of 1-80 Hz to compare as shown in the figure 2-7 or 2-8.

If RMS of acceleration of the highest stripe is equal or higher than value defined at 2-7 or 2-8 for touching duration or touching duration is more than TLV allowed, the highest axis must be drawn to meet with the graph that required the lowest duration of exposure.

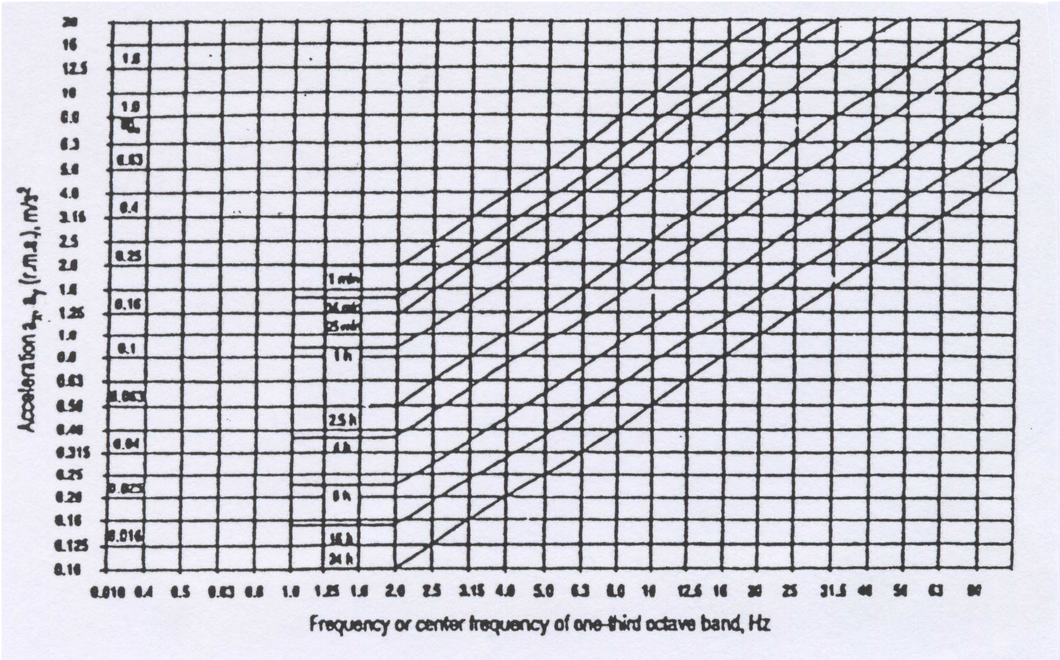


Figure 2-7 Acceleration (a_z) expressed as frequency and duration of exposure, adapting from ISO 2631

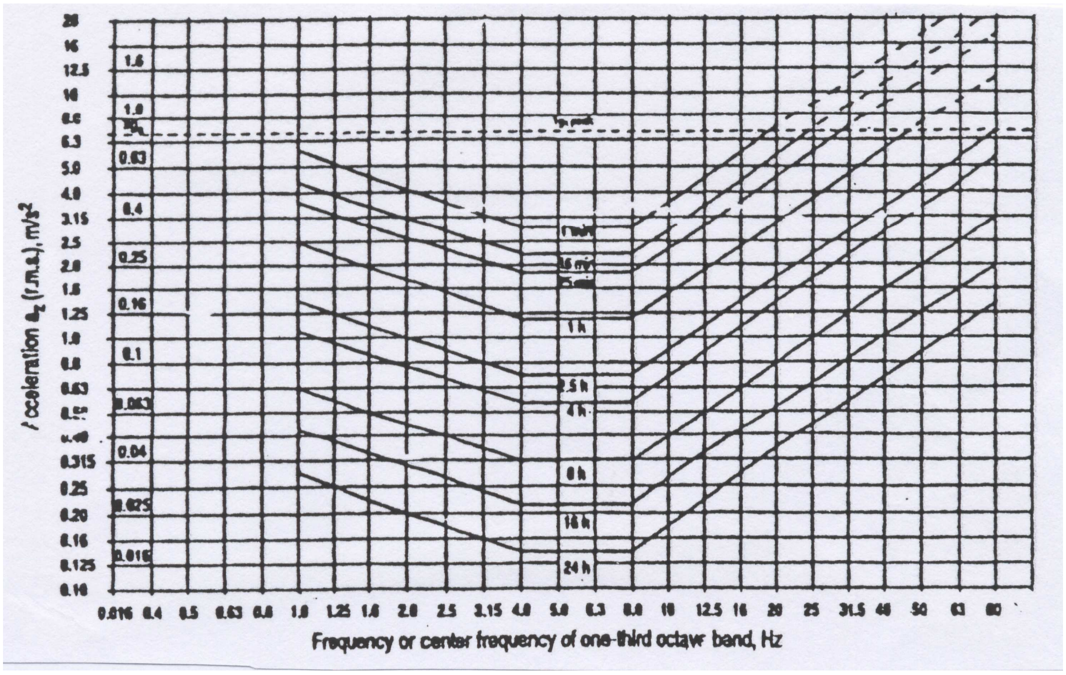


Figure 2-8 Acceleration (a_x, a_y) expressed as frequency duration of exposure, adapting from ISO 2631

Table 2-2 Velocity of longitudinal vibration a_z, (feet - head) (see figure 2-7), TLV is defined as RMS of vibration in single frequency or RMS of vibration in various frequency in 1/3 Octave band (adapted from ISO 2631).

Frequency	Acceleration (m/s^2) Duration of exposure								
	24 hr	16 hr	8 hr	4 hr	2.5 hr	1 hr	25 min	16 min	1 min
1.0	0.280	0.383	0.63	1.06	1.40	2.36	3.55	4.25	5.60
1.25	0.250	0.383	0.56	0.95	1.26	2.12	3.15	3.75	5.00
1.6	0.224	0.302	0.50	0.85	1.12	1.90	2.80	3.35	4.50
2.0	0.200	0.270	0.45	0.75	1.00	1.70	2.50	3.00	1.00
2.5	0.180	0.239	0.40	0.67	0.90	1.50	2.24	2.65	3.55
3.15	0.160	0.212	0.355	0.60	1.80	1.32	2.00	2.35	3.15
4.0	0.140	0.192	0.315	0.53	0.71	1.18	1.80	2.12	2.80
5.0	0.140	0.192	0.315	0.53	0.71	1.18	1.80	2.12	2.80
6.3	0.140	0.192	0.315	0.53	0.71	1.18	1.80	2.12	2.80
8.0	0.140	0.192	0.315	0.53	0.71	1.18	1.80	2.12	2.80
10.0	0.180	0.239	0.400	0.67	0.90	1.50	2.24	2.65	3.55
12.5	0.224	0.302	0.50	0.85	1.12	1.90	2.80	3.35	4.50
16.0	0.280	0.383	0.63	1.06	1.40	2.36	3.55	4.25	5.60
20.0	0.355	0.477	0.80	1.30	1.80	3.00	4.50	5.30	7.10
25.0	0.450	0.605	1.0	1.70	2.24	3.75	5.60	6.70	9.00
31.5	0.560	0.765	1.25	2.12	2.80	4.75	7.10	8.50	11.2
40.0	0.710	0.955	1.60	2.65	3.55	6.00	9.00	10.6	14.2
50.0	0.900	1.19	2.0	3.35	4.50	7.50	11.2	13.2	18.0
63.0	1.120	3	2.5	4.25	5.60	9.50	14.0	17.0	22.4
80.0	1.400	1.91	3.15	5.30	7.10	11.8	18.0	21.2	28.0

Table 2-3 Velocity of Lateral vibration ax or ay (back to chest or left side to right sideways) (see figure 2-8), TLV is defined as RMS of single frequency vibration or RMS of vibration in various frequency in 1/3 Octave band (adapted from ISO 2631)

Frequency	Acceleration (m/s^2) Duration of exposure								
	24 hr	16 hr	8 hr	4 hr	2.5 hr	1 hr	25 min	16 min	1 min
1.0	0.100	0.135	0.224	0.355	0.50	0.85	1.25	1.50	2.0
1.25	0.100	0.135	0.224	0.355	0.50	0.85	1.25	1.50	2.0
1.6	0.100	0.135	0.224	0.355	0.50	0.85	1.25	1.50	2.0
2.0	0.100	0.135	0.224	0.355	0.50	0.85	1.25	1.50	2.0
2.5	0.125	0.171	0.280	0.450	0.63	1.06	1.6	1.9	2.5
3.15	0.160	0.212	0.355	0.560	0.80	1.32	2.0	2.36	3.15
4.0	0.200	0.270	0.450	0.710	1.0	1.70	2.5	3.0	4.0
5.0	0.250	0.338	0.560	0.900	1.25	2.12	3.15	3.75	5.0
6.3	0.315	0.428	0.710	1.12	1.6	2.65	4.0	4.75	6.3
8.0	0.40	0.54	0.900	1.40	2.0	3.35	5.0	6.0	8.0
10.0	0.50	0.675	1.12	1.80	2.5	4.25	6.3	7.5	10.0
12.5	0.63	0.855	1.40	2.24	3.15	5.30	8.0	9.5	12.5
16.0	0.80	1.06	1.80	2.80	4.0	6.70	10.0	11.8	16.0
20.0	1.00	1.35	2.24	3.55	5.0	8.5	12.5	15.0	20.0
25.0	1.25	1.71	2.80	4.50	6.3	10.6	15.0	19.0	25.0
31.5	1.60	2.12	3.55	5.60	8.0	13.2	20.0	23.6	31.5
40.0	2.00	2.70	4.50	7.10	10.0	17.0	25.0	30.0	40.0
50.0	2.50	3.38	5.60	9.00	12.5	21.2	31.5	37.5	50.0
63.0	3.15	4.28	7.10	11.2	16.0	26.5	40.0	45.7	63.0
80.0	4.00	5.4	9.00	14.0	20.0	33.5	50.0	60.0	80.0

Table 2-4 Balance Weight related to the frequency of the highest acceleration. Responded graph is presented as figure 2-7 and 2-8 (adapted from ISO 2631)

Frequency	Balancing weight	
	Longitudinal vibration	Lateral vibration
1.0	0.50	1.00
1.25	0.56	1.00
1.6	0.63	1.00
2.0	0.71	1.00
2.5	0.80	0.80
3.15	0.90	0.63
4.0	1.00	0.5
5.0	1.00	0.4
6.3	1.00	0.315
8.0	1.00	0.25
10.0	0.80	0.2
12.5	0.63	0.16
16.0	0.50	0.125
20.0	0.40	0.1
25.0	0.315	0.08
31.5	0.25	0.063
40.0	0.20	0.05
50.0	0.16	0.04
63.0	0.125	0.0315
80.0	0.10	0.025

a. 4-8 Hz resonance vibration is $\pm a_z$
   1-2 Hz resonance vibration is $\pm a_z$ or $\pm a_z$

In short term exposure to vibration with high amplitude and severe intensity together with higher crest factor more than 6 may happen during the working day. In this case TLV may unable to protect the workers.

Table 2-5 ACGIH TLV's – maximum frequency – weighted Z – axis RMS acceleration

Duration	Acceleration, m/s^2
1 min	2.80 m/s^2
16 min	2.12 m/s^2
25 min	1.80 m/s^2
1 hr	1.18 m/s^2
2.5 hr	0.71 m/s^2
4 hr	0.53 m/s^2
8 hr	0.315 m/s^2
16 hr	0.192 m/s^2
24 hr	0.140 m/s^2

Table 2-6 ACGIH TLV's–maximum frequency–weighted X & Y axis RMS acceleration

Duration	Acceleration, m/s^2
1 min	2.0 m/s^2
16 min	1.50 m/s^2
25 min	1.25 m/s^2
1 hr	0.85 m/s^2
2.5 hr	0.50 m/s^2
4 hr	0.355 m/s^2
8 hr	0.224 m/s^2
16 hr	0.135 m/s^2
24 hr	0.100 m/s^2

The standards and guidelines concerning whole-body vibration are designed to reduce vibration to a level where most workers can perform job tasks without discomfort.

The most widely used document on this topic is guide for the evaluation of human exposure to whole-body vibration (ISO 2631). These exposure guidelines have been adopted as ACGIH TLVs. The ISO standard gives three different types of exposure limits:

- A reduced-comfort boundary
- The fatigue-decreased proficiency boundary
- An exposure limit

The reduced-comfort boundary is for the comfort boundary is for the people traveling in air planes, boats and trains. Exceeding these exposure limits makes it difficult for passengers to eat, read or write when traveling. The fatigue-decreased proficiency boundary is a limit for time-dependent effects that impair performance. For example, fatigue source limit is used to assess the maximum possible exposure allowed for whole-body vibration.

A separate set of “severe discomfort boundaries” is given for 8-hour, 2-hour and 30-minute exposures to whole-body vibration in the 0.1 Hz to 0.63 Hz range. As with all standards, it is important to read and understand all the information before applying it in the workplace.

Directive 2002/44/EC of the European Parliament and of the Council (EC) suggested the use of acceleration 0.5 m/s^2 as the action level and 1.15 m/s^2 as limit level of exposure 8 hours per day. For total mean at balancing weight of RMS at acceleration. That includes pro visions for mandatory phase-out of non- conforming equipment.

8-hour Daily Exposure Limit	Action Level	Limit Level
Hand-Arm	2.5 m/s^2	5 m/s^2
Whole-Body	0.5 m/s^2	1.15 m/s^2
Whole-Body (vibration dose)	9.1 m/s^2	21 m/s^2

2.13 Vibration Control (7)

Vibration control can be done in various ways:

1. Source of vibration control should be eliminated by using vibration reducing materials to support the machine base and absorb vibration at the handle or grips of the vibrated machines. Moreover, the regular preventive maintenance is needed must be immediately to prevent vibration malfunction of machines corrected or fixed and using materials or technical with proper design.
2. Receiver vibration-reducing should use personal protective devices such as special gloves and shoes with materials to absorb vibration at the heel, cushion and head rest.
3. Administrative controls can be important. Job rotation, work and rest periods can help reduce the risk for workers who work related with vibration.

Controlling whole-body vibration of vehicle drivers can be done by using hanging cushion or hanging part of the roof, performing preventive maintenance of anti-vibration system of vehicles, checking air of vehicle tires and using remote control with the process which caused vibration. The chair with arm rest, adjusted waist support and adjusted seat is the very helpful.

2.14 Vibration Reducing Materials (14,15,16)

Another method for vibration reduction is the installation of vibration prevention pedestal involved with High Elasticity to reduce vibration frequency during the normal machine operation and minimize damping for low frequency vibration such as the frequency at the start of the machine. Vibration prevention pedestal is being used for 2 purposes, the reduction of Active Isolation and Passive Isolation. Generally there are 2 types of vibration prevention pedestal based on type of material including metal spring, rubber spring and metal fiber spring.

In case of the machine that needed protection at the base to reduce vibration from transmitting to other machines, the machine should be fixed as a part of the building floor and placing on the elastic and flexible materials. Installing the elastic flexible materials between the machine and the building floor may reduce rigidity of the connected line and capacity of the machine. This problem can be solved by starting from using Inertia Block as well as saving the construction cost. No matter which type of Inertia Block used with any type of the machine, vibration amplitude can be reduced. Even though setting elastic materials between the machine and the building floor can reduce vibration, soil physical property and energy transmitting capability must also be considered.

Controlling or reducing whole-body vibration resulted from machine vibration passing to the worker's body can be done with many tools such as using spring, materials to support the machine, stand to support the machine base. Support at the base can reduce vibration with the use of flexible materials with pores. The support materials should have elasticity and pores such as rubber-in-sheer, ribbed rubber and rubber-and-cork or other materials with similar properties. Using glass-fiber pads can reduce vibration also. The ability to reduce vibration depended on size and strength of the materials, type of fiber for making materials.

Furthermore using the materials such as hard wood, block brick and woods chips to support the machine base as the wooden pillow can reduce vibration passing from the machine to the worker. Type of vibration prevention:

2.14.1 Rubber Springs

Most rubber springs made from natural fiber mainly because of high resistance and strength with more ability to withstand vibration. It has the strength of 68-80 Shore A. Furthermore, other types of materials are being used also such as Silicone with ability to withstand higher temperature and damper than natural rubber for vibration reduction in the low frequency interval or constantly changing machine frequency. The installation of the rubber springs must be designed with compression or shear because of the following reasons:

- Compressive strength with maximum value higher than Shear strength 5-10 times and having the lowest minimum in Tensile strength.

- The design of the rubber to support the tension with high risk of damage from reducing the support area. When the crack in the rubber happened, it would tear quickly.

Choosing each type of the rubber spring must fit properly with nature of work. For example, the certain type of the spring is designed to support both vertical and side ways pressure. However, using the rubber spring has limitation because it cannot be used with temperature higher than 70 Celsius, in strong sunlight and directly mixed with oil. Then Tensional rubber springs must be designed so that rubber installation can withstand any type of shear strength.

2.14.2 Metal Mesh Springs

Metal Mesh Springs are consisted of Stainless steel. Long metal is being pressed into different designs to gain high spring's elasticity as well as increasing Damping factors much higher than natural rubber which reducing strike force better than metal springs and natural rubbers and be more suitable for the machines in molding designs and works required high temperature. This type of spring is expensive and not suitable with the work involving with dust or sands because they would embed between the space and metal fibers, causing the loss of elasticity and damage of the springs.

2.15 Rubbers (17)

Rubbers have similar molecule structure to natural rubber. Sometimes, adding copolymer made molecule net spread wider before adding the sulphur mixture and doing vulcanization and lubing. Rubbers are divided into 2 types as follows:

2.15.1 Natural rubbers

Natural rubbers is the polymer derived from rubber trees as monomer, namely Isoprene connected from 1,500 to 15,000 units (Molecular structure is cis as the group of the similar structure staying on the same size of double bond.). Most natural rubber derived from Hevea Brazilliensis trees which originated from Amazon River in South America. Fresh latex from the tree has dense white color with dry rubber, about 30% suspended in the water. After passing centrifuge process until the amount of dry rubber increased to 60 percent, so called concentrated latex. Adding ammonia can preserve the condition of concentrated latex for lengthy storage. Certain proportion of concentrated latex would be exported and the remainder used as raw material in the rubber gloves and condom industry. By adding acid in fresh latex, the latex particles would attach together to become solid and separate themselves from water. Then, pressing rubber into thin sheet with two-roll mill and sun dried to get rid of moisture before baking with smoke at the estimated temperature of 60-76 C for 3 days. The finished product is the smoke rubber sheet.

Besides using smoke rubber, most industries have substituted chunk rubber as raw material because chunk rubber quality is more stable than smoke rubber as well as passing the test and being classified for quality control based on the principles of raw materials production. The raw material of the chunk rubber production is latex or rubber sheet depended on the grade of produced chunk rubber. For example, producing the chunk rubber grade STR5L which has very light color required latex as the raw material. In the case of STR20 production which is highly contaminated mixture and dark color the rubber sheet or leftover rubber may be used as raw material. The rubber production process is rather complicated, involving with expensive machines and quality control regularly. Therefore, chunk rubber is more expensive than smoke rubber sheet.

The chemical name of natural rubber is cis-1, 4-polyisoprene by having isoprene (C5H8) with n value from 15-20, 000 because the component of natural rubber is non-polar. So, natural rubber can dissolve well in non-polar solvent such as Benzene and Hexane. Generally natural rubber has amorphous molecule structure, but in some condition, the molecule of rubber can be arranged to be in order at the low temperature to form crystallize. Low temperature crystallization would make rubber be stronger. If the temperature increased, rubber would turn soft and return to normal stage while strain induced crystallization created tensile strength and tear resistance as well as giving high abrasion resistance.

Another part of natural rubber is Cutta Rubber derived from Cutta trees, Bara trees and Sicle trees. Cutta rubber is different from Bara rubber where the molecular structure is Trans (Molecule with similar group facing on opposite side of double bond).

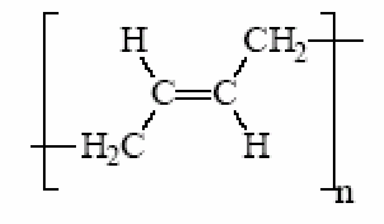


Figure 2-9 Bonding Molecular Structure as Trans of natural rubber

Another outstanding feature of natural rubber is elasticity. Natural rubber has high elasticity. When the external force disappeared, rubber would return to the normal stage and size (or nearly the same) quickly. Natural rubber is also possessed excellent tack ability which is necessary for the process of assembling the different parts together such as rubber tires.

However, raw rubber alone has limited property in performance because of mechanic property and unstable physical property depended on extreme changes in temperature. Rubber turns soft and sticky in heat but tough and brittle in low temperature. With these reasons, rubber must be mixed with other chemicals such as sulfur, black carbon and other solutions. After grinding, rubber compound is ready for vulcanization. This is called “vulcanizate”. The property of vulcanizate rubber is stable and not varied with temperature much as well as having better mechanic property.

Natural rubber is being used in the production of many rubber products because of the following reasons:

- Natural rubber has excellent tensile strength without adding strength solution and possessed high elasticity that is suitable for producing certain products such as rubber gloves, condom and rubber bands
- Natural rubber has good dynamic properties with high elasticity and slight heat build-up as well as having good tack property that is suitable for producing the rubber tires for trucks, airplane or mixing with synthetic rubber in the automobiles tires industry.
- Natural rubber has high tear resistance both in low and high temperature, suitable for making hot water pouch because the design must be removed from the mold while it is still hot. Therefore, rubber must have high tear resistance during extreme heat.

Even with good properties for making the different rubber products, natural rubber has certain disadvantage in quickly degenerated under the sun, Oxygen, Ozone and heat because the rubber molecules contain a lot of double bond which make rubber quickly react to Oxygen and Ozone by having sunlight and heat as the catalyst. Therefore, during production, some chemical such as antidegradants must be added to extend shelf life of the products. Furthermore, natural rubber has low capacity to withstand non-polar, oil and chemical, so it is unsuitable for the production of the products that contact with such chemicals.

2.15.2 Synthetic rubbers

Synthetic rubbers (SR) are imitation of natural rubber such as Polybutadiene (as Monomer) rubber, SBR (Styrene-Butadiene Rubber). After passing vulcanization, synthetic rubbers would be more elastic than natural rubbers.

Vulcanization is the improvement of the rubber quality by making rubber reacted with sulphur in the proper amount at temperature higher than the melting point of sulphur. It makes rubber be more stable at various temperatures. Adding sulphur would generate Covalence bone between Polyisoprene chain and connection linking between polymer chains with rubber sulphur atom. Rubber that already passed vulcanization with more stable at various temperatures is called Vulcanizates rubber.

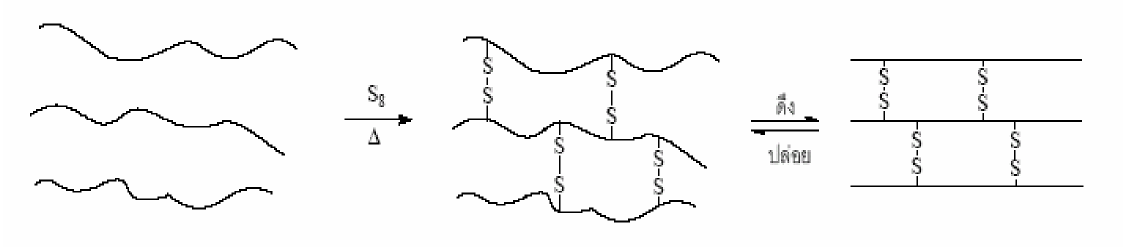


Figure 2-10 Vulcanization

2.15.2.1 Styrene-butadiene rubber

SBR is consisted of styrene monomer estimated 23.5 percent and butadiene copolymer estimated 76.5 percent. Both monomers line up as random copolymer. Moreover, molecule chains of SBR is not in order, so crystalline cannot form when being captured. Then, rubbers usually have low resistance and require reinforcing filler support.

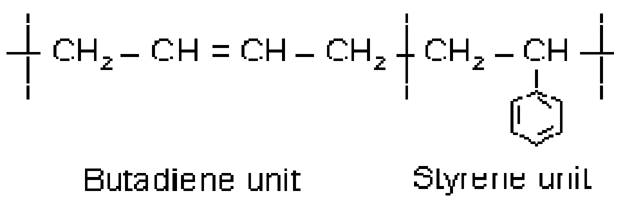


Figure 2-11 Structure of SBR

SBR is used in the same way as natural rubbers and IR because of its ability in wide production. In comparison with natural rubbers, SBR maintains consistent quality. Therefore, SBR is suitable for many types of works because of its stable property and less contaminated substances. Importantly, there is no need for mastication before mixing chemicals during the production process. Because SBR is being synthesized to maintain low molecular weight, it has proper stickiness for chemical to spread well and the rubber can flow easily during molding. Therefore, SBR has simpler production process, more economical and saved more time and production cost. However, because of double bond in the molecule of SBR, it has degenerated quickly in Oxygen, Ozone or sunlight as well as natural rubber, only with lower elasticity than natural rubber. SBR has almost the same oil tolerance as natural rubbers. SBR that reinforced with strength solution such as black carbon would be able to withstand more scraping, only lower tear resistance than natural rubber.

SBR is used in the production of rubber belt, shoes soles, electrical wire insulator, rubber tube, rubber medical supplies, foods containers and importantly SBR is used in the production of small vehicles tires by mixing with other types of rubbers such as BR and NR. The reason for not being able to use only this by type of rubber in the production of vehicle is this type of rubber accumulated extreme heat during the process as compared with natural rubbers and butadiene rubbers.

2.15.2.2 Chlorophene (CR)

The trade name of CR is neoprene as being the synthesis rubber from chloroprene monomer. CR molecule can line up neatly under the proper condition. This type of rubber can crystallize the same way as natural rubber which make CR able to withstand high tension (without adding the same solution). Furthermore, it has high resistance to tearing and abrasion.

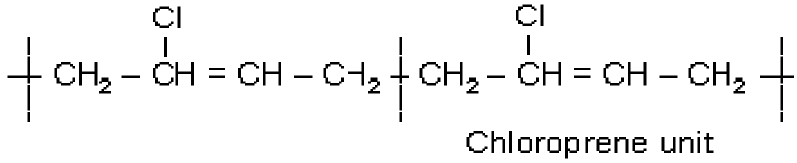


Figure 2-12 Structure of CR

Solid CR is divided for general use and specific use based on Grades of Solid CR. Grade G, W and T are used for general works and grad AC, AD, AG and FB are used in the specific works for making rubber glue, coating and sealants. CR structure depended on the temperature of Polymerized and directly affects the crystallization or rubber elasticity. If the temperature of Polymerized gets higher, the rubber structure would become less stable with irregular molecular structure and lower crystallization. On the contrary, CR derived from Polymerized at low temperature has higher crystallized which is the desired trait for glue production that required sudden stickiness. However, this rubber grade is not suitable for other productions because this type of rubber would become harder and loss elasticity quickly. Therefore, proper CR in the production of regular products must be the one with less crystallized.

CR has property quite similar to natural rubber by having good tack property used in the process of assembling the parts. CR can flow well to join together without making obvious mark in the connection of piecework during molding. This rubber is the rubber with the core because it contains atom of chorines. Therefore, in comparison with non-polar rubber, findings indicated that CR could withstand swelling in the oil quite well (less inferior than NBR). Furthermore, chorine atoms make CR resist flame weather and Ozone. However, chlorine atoms affect the electrical property of rubber by making it has high conductivity. CR is being classified as “antistatic” rather than being the insulator. Therefore, this type of rubber can be used as outer cover of cable line instead of being cable insulator.

CR that can crystallize from less to moderate level are used widely in the products that required good mechanics which with stand fire, oil, normal weather and ozone. CR is being used in the production of seal rubber, hose, rolling, belt and V-belt, bearing, lining for sole and rubber products used in the construction such as window and roof edges and cable cover. As for CR most crystallized is widely used in the glue production.

2.16 Primary Data for designing Vibration Prevention Base (16,18,19,20)

2.16.1 Problems during operating machine

- Cracking at the machine base attached to the machine legs
- Creating loud noises
- Feeling vibration passing through the body
- Other problems

1.16.2 Nature of machine work

- Type of machine for operation
- Location of each machine at each floor and conditions of the floor underneath the machine
- Weight of machine and other equipment on the machine pedestal
- Lowest and highest velocity and normal velocity
- Any strike force
- Numbers of legs at machine pedestal
- COG position to calculate weight in each support point

2.16.3 Desire traits

- Desire to reduce vibration from the machine to the floor
- Desire to reduce external vibration pass to the machine
- Whether the machine needs to maintain the deflation level of machine constantly
- Acceptable level of machine deflation

2.16.4 Surrounding environment

- Temperature
- Chemical
- Corrosion

2.16.5 Natural frequency of the structure after the installation

Natural frequency is the independent frequency of the structure or response frequency happened after receiving external force, especially being specific value of such structure. This vibration would continue and gradually reduce with internal resistance or Damping of such structure.

Most producers would give the natural frequency stated in the manual depended on deflection period after installation. The natural frequency would vary with deflection period of the spring. Generally, natural frequency can be found by Bump Test and calculation.

In the experiment, tools used for Spectrum Analysis must be set up the measured head with the structure in the same direction before generating external force by tabbing one time at the structure. Vibration would be recorded with amplitude and frequency in the tool used for measurement and analysis of frequency. Derived frequency is truly natural frequency.

Calculation of the Natural Frequency for the metal spring (in theory there is no Damping) is related to deflection period and Stiffness in linear that can be calculated as follows:

$$\text{Natural Frequency, } f\text{n} = \frac{300}{\sqrt{S}} \quad \text{(rpm)}$$

$$\text{Natural Frequency, } f\text{n} = \frac{5}{\sqrt{S}} \quad \text{(rpm)}$$

Given S = Deflection (cm.) for the metal spring

S = Sub-Tangent (cm.) for the rubber spring

Since the rubber spring associated with spring deflection and Nonlinear stiffness by engaging Sub-Tangent in the calculation to define longitudinal graph (the machine weight) and drawing in lateral to cross with the curve line as association of deflection-stiffness. From there finding the steepness at the curve surface at the cross point, then dragging the line to cut at the lateral graph line to get Sub-Tangent value. For the metal spring δ = S. Deflection period for calculation of the natural frequency should derive from the period of touching Niche spring curve at the stiffness position (S period). In case where the spring is the metal S = δ.

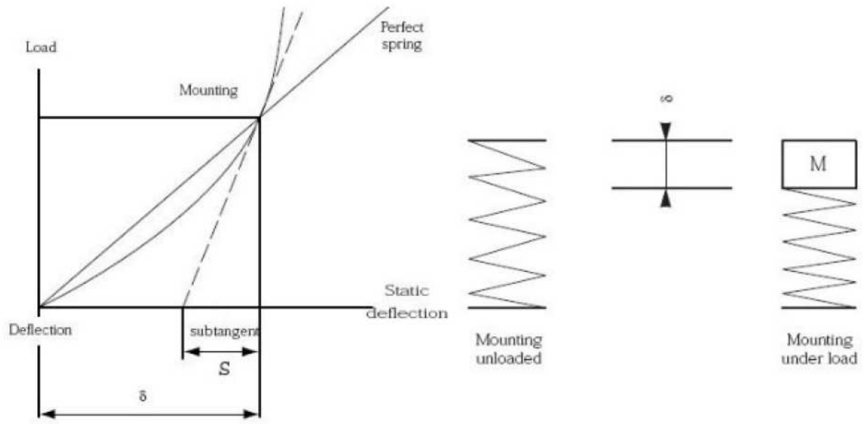
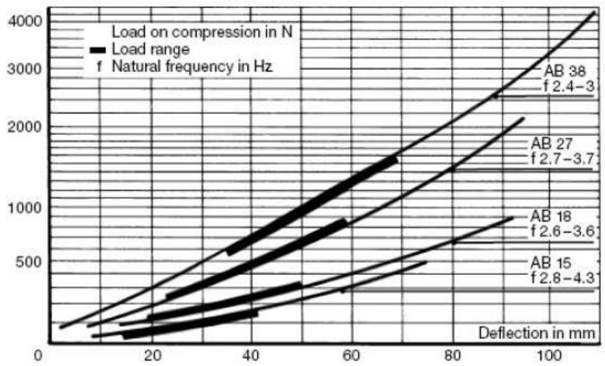


Figure 2-13 Graph presenting relationship between deflection of the metal spring as linear and the rubber spring for nonlinear (Curve)

In general, the producers would give the value of the natural frequency along with the manual which should be expressed as the curve of niche spring or being the interval based on stiffness. The deflection period would be varied with the force of pressure which varied with the natural frequency as shown in the figure 2-14.



Type	G	A un-loaded	A max. load	B un-loaded	B max. load
AB 15	50 – 160	165	120	70	89
AB 18	120 – 300	203	150	87	107
AB 27	250 – 800	230	170	94	114
AB 38	600 – 1600	295	225	120	144

Figure 2-14 The rubber Niche Spring in each line related to the Rubber Spring in each model as the thick line is the interval for use and the natural frequency

Calculation Procedures

1. Calculate the machine weight per the number of vibration protection pedestal to choose the proper size.

2. Calculate proportion between the natural frequency (fn) and Proportion of frequency (fe) as follows:

Proportion of frequency = $\frac{fe}{fn}$

Generally, existing problems are divided into 2 types, from vibration and striking. In theory, Proportion of frequency is the indicator of the following:

- Considering as vibration when the frequency proportion $>\sqrt{2}$ (Isolation Range, V <1)
- Considering as striking when the frequency proportion $\leq \sqrt{2}$ (Amplification Range, V≥1)

The proportion of frequency as equal as 1 or natural frequency because being the cause of Resonance which create more vibration and damage to the machine.

The proportion of frequency must have value larger than $\sqrt{2}$ in order to reduce transmissibility which can be seen in the shade area of the graph and found transmissibility from the figure. If the proportion of frequency is $\leq \sqrt{2}$, it must be considered striking problem instead. Then, the more the proportion of frequency, the transmissibility became less.

There is only one value of proportion of frequency for different type of support pedestal, but the ability to reduce vibration may vary differently depended on Damping factor (D) of different material as shown in the shade area of the graph 2-15 (the proportion of frequency larger than $\sqrt{2}$) which is the interval for reduction in vibration.

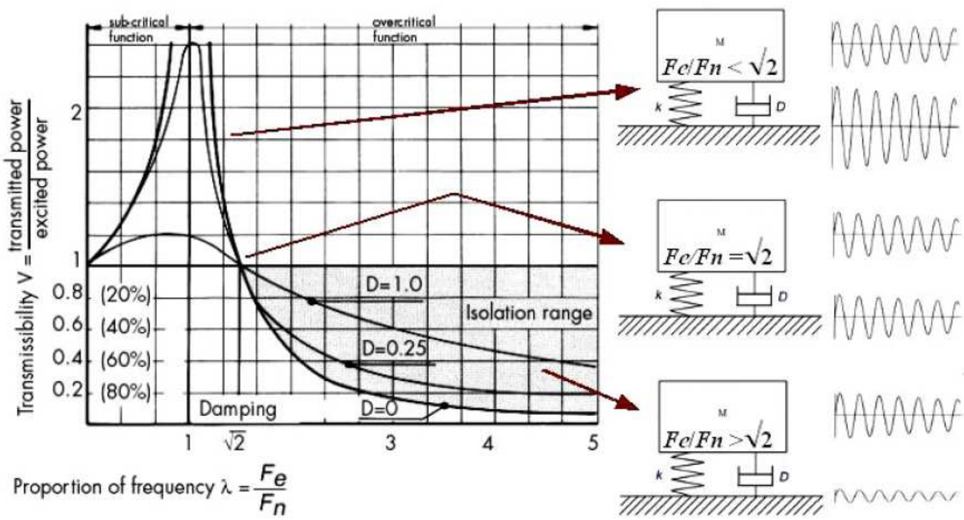


Figure 2-15 Graph showing association between the Transmissibility in longitudinal axis and Proportion of frequency in lateral axis

3. Finding effectiveness in vibration reduction from transmissibility in the figure 2-15. The longitudinal axis is the ability of Transmissibility (V) and the lateral axis is the proportion of frequency. Findings from the graph indicated that if the proportion of frequency is higher than $\sqrt{2}$, it would reduce transmissibility. Based on 100 percent, reduction of vibration in term of Isolation is calculated as follows:

$$\text{Isolation (\%)} = 100(1-V)$$

$$V = \frac{B}{A}$$

$$v = \sqrt{\frac{[1+(\frac{2*fe}{fn}*D)^2]}{[(1-\frac{fe^2}{fn^2})^2+(\frac{2-fe}{fn2}*D)^2]}}$$

Given V = Transmissibility Value

A = Size of inbound vibration

B = Size of outbound vibration

*f*e = Stimulated Frequency (Machine)

*f*n = Damping Factors

Table 2-7 Damping Factor and Transmissibility at Vmax (Vmax, *f*e = *f*n)

Material	Damping Factor, D
Steel Spring	0.005
Natural Rubber	0.05
Neoprene	0.05
Butyl	0.12
Metal Mesh	0.12
Air Damping	0.17
Felt and Cork	0.06

Calculation expressed as percentage of vibration reduction of Natural Rubber is shown in the Table 2-8 as follows:

Table 2-8 Percentage of vibration reduction based on Proportion of Frequency and Transmissibility at Vmax (Vmax, *f*e = *f*n)

Proportion of frequency	% Isolation
1	Resonance
1.414	0
1.5	19
2	66
2.5	80
3	87
3.5	90
5	95
7	97
10	98
12	99

Sub-Tangent and the Frequency of the Machine can be analyzed out the natural frequency of the material for vibration reduction to know the efficiency of vibration reduction of such materials from graph in figure 2-15

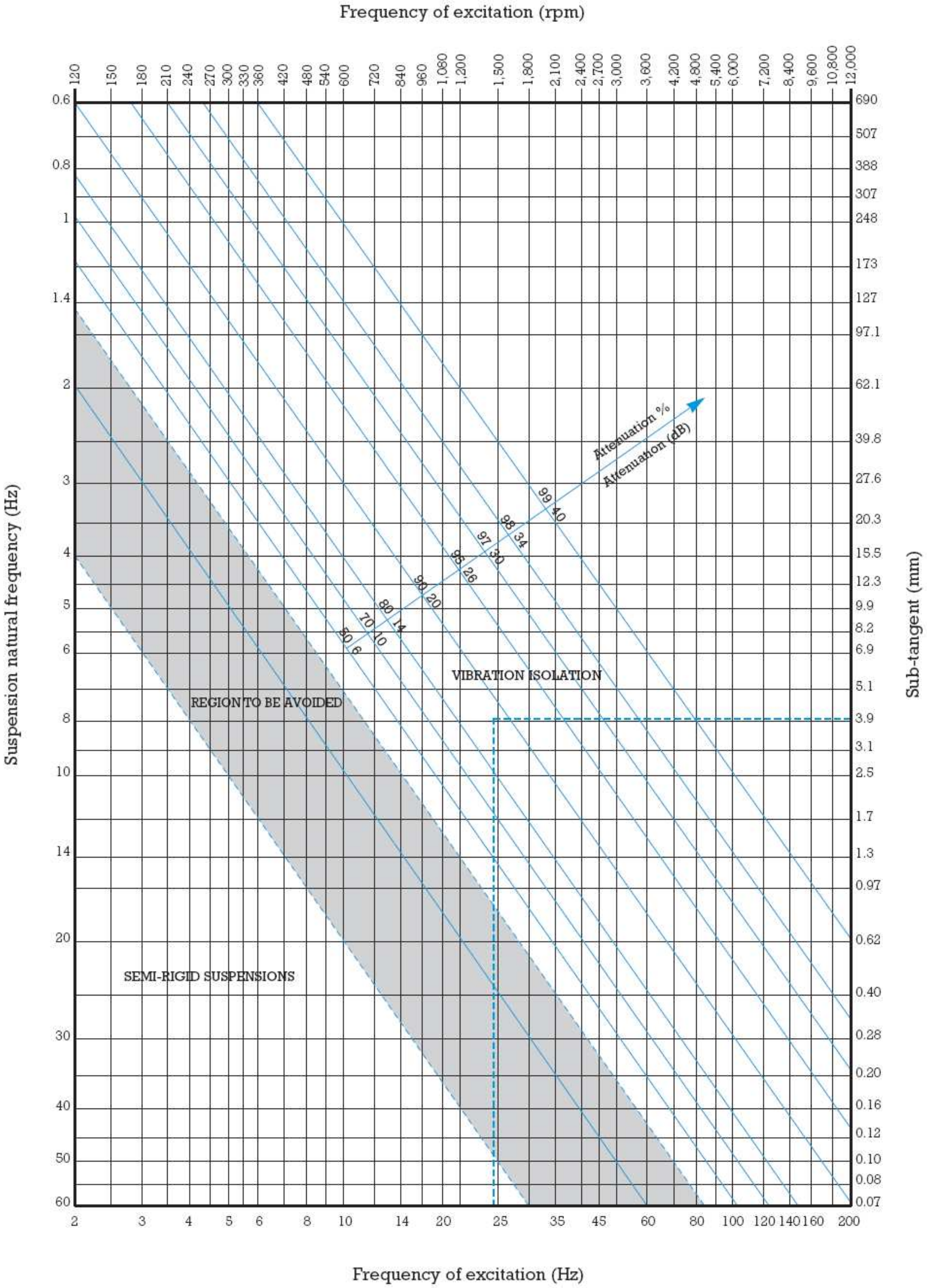


Figure 2-16 Relationship between Sub-tangent, frequency of machine, Suspension natural frequency and efficiency of vibration reduction

Review of Researches Study

Mutsumato and Griffin (21) studied the effect of vibration and the vibration entering the body longitudinal and responses from the respondents by testing vibration at the frequency in the range of 3 and 9 Hz and frequency vibration at 3 and 12 Hz with the acceleration of 1.0 m/s^2 as well as increasing vibration level and test vibration. Findings from the effect of vibration level towards discomfort feeling from both types of vibrators indicated that increasing vibration volume 6-12 percent continuously and vibration increased the discomfort with statistical significance.

Randall, Matthews and Stiles (22) studied the industry effecting from vibration into the worker's body. Long-term effects were tension and discomfort feeling. Resonance frequency occurred within the body tended to replace in internal organs and skeleton. Therefore, longitudinal vibration entering the body of 113 workers standing while packing ready-made clothes was measured at the axis and maintained vibration at the low level at the samples' feet. Overall frequency results of resonance found was 9-16 Hz which independent from the weight, having the Mean at 12.2 (+/-) 0.1 Hz for female workers and 12.8 (+/-) 0.2 Hz for male workers and the Mean for total population was at 12.3 (+/-) 0.1 Hz.

Dupuis and Zerlett (22) studied the vibration entering the body and the abnormality of backbone through the interview and medical check-up among 352 workers working with Earth-Moving Machines at least 3 years. X-ray of skeleton from 251 machine operators indicated that at workers who had been working at least 10 years started to experience changes in the backbone while 149 workers felt sudden discomfort after 8 hours work. A group of people with the symptom was compared with reference group of 215 persons. Percent of testing subject experienced the discomfort at the backbone was 68.7 percent. Among machine operators, 6.8 percent felt discomfort at the Thoracic and 18.2 percent at the Cervical. Discomfort feeling resulted from vibration entering the body and depended on age also.

Seidle (23) studied sickness caused by vibration which resulted from low frequency vibration entering the body causing irregularity in the system of control nerve, queasiness and digestive system that was not caused by vibration entering the body only, but associated with working conditions which causing certain symptoms after vibration entering the body for long time. These symptoms occurred with female reproductive system such as irregular menstruation, fetus position in the uterus, pregnancy problems and miscarriage and delivered still born. Vibration also created side effects, including hearing reduction and distorting backbone structures among workers who operate the vibrated machines.

Kabacinska, Paradowski and Kwaitkowski (24) tested 47 males who had received vibration into the body for over 9.8 years. Testing was done to find the capacity of food passage, maximum pressure within food passage and within the stomach, Mean and maximum of ticking within the stomach. Findings indicated that (1/4) of vibration entering the body created abnormality in the control system for digestion.

James (25) studied whole body vibration among factory workers in one of printing factory by installing measure valve near the place where the workers stand working to measure vibration in the recording machine. Results were translated by making comparison with comfortable and safety levels in accordance with ISO standard, findings indicated that workers who were working with small printer had the smallest risk in receiving vibration.

Thomas C Jetser (26) studied the development of gloves for reducing vibration at the worker's hands made from various materials, namely viscoelastic material, basically sorbothane and viscolas. Findings indicated that these materials could prevent vibration well in high frequency, but prevent vibration in medium and low frequency only little. The gloves used while performing work were not fit properly and too hard to wear.

Veejay (27) studied the reduction of vibration from 3 different types of gloves, Leather gloves, Poron gloves, Sorbot-hane gloves by making comparison between use and non-use of the gloves among workers who operated the metal extract machine. Findings indicated that wearing Leather gloves could reduce vibration 23.5 percent, wearing Poron gloves decreased vibration 24.2 percent and wearing Sorbot-hane gloves decreased vibration 45.5 percent as compared to non-wearing.

Raynold D D (28) studied vibration protection gloves made from air bladder, gelform, sorbothane, vircolas and akton. Findings indicated that air bladder gloves are the most effective. Gloves made from gelform, sorbothane, viscolas and akton are too stiff.

Nikhom Thumpanya (29) studied vibration protection gloves made from 3 types of materials. Findings indicated that leather gloves could reduce vibration about 35.18 percent. From the study of vibration reduction through wearing leather gloves with different frequency, findings indicted that leather gloves reduced vibration well at 100 Hz and 125 Hz.

Polchit Buokaew, Varaporn Kajornchaikoon and Associates (30) studied the formula and method for the rubber production for supporting the machine with natural rubber that already been processed and returned to natural form for almost 100 percent suitable for engineering work. The processed rubber was applied with designed formula to support different weight. When it was used together with the metal, it could be flexible and support vibration well. Testing rubber strength with the black soot N330, Selica and Aromatic oil, indicated that using black soot N330, Selica 2-3 would increase rubber strength about 1 unit shore A.

Chuck Jantalukana (31) studied vibration control with the thin sheet by restraining the sheet layers under the control from pulling the control sheet with the use of viscoelastic or elastomer as well as increasing restraint coefficient by attaching another thin sheet to succeed at more reduction of vibration.

Pornthip Yenjai (32) studied by making comparison in vibration at the grinding stone worker’s hand with and without wearing 3 types of gloves including, Lycra with viscoelastic, Polyurethane with viscolastic and leather furniture gloves and using these glove materials to cover the tool’s handle. From the result of studying vibration in each frequency and total frequency in 3 axes, indicated that gloves and materials made from Lycra cotton and Polyurethane could reduce vibration at the frequency of 16, 125, 250 and 500 HZ. Furniture leather gloves only reduced at frequency 16 Hz, but the same material covers the handle reduced frequency at 16, 125, 250, 500 and 1000 Hz. The most effective gloves in vibration reduction overall as compared to Lycra cotton gloves had the value of 39.96 percent. For furniture leather material covered the handle had the value of 38.84 percent.

CHAPTER III
MATERIALS AND METHODS

3.1 Study Designed

This research was the experimental study and comparison of vibration reduction materials to support machinery, namely the rubber belt plate and the rubber valve plate.

3.2 Population

Populations in this study are TOYOTA weaving machines model JAT710 Air Jet and areas surrounding the weaving machine and the vibration reduction sheets used for supporting machines.

3.3 Sample Size

Experiment was done with the weaving machine in the factory at 4 bases of the machine and 6 points on areas surrounding machines by repeating the same measurement at each points 5 times without using vibration reduction sheets and using both types of sheets for total 150 samples.

3.4 Materials

Materials used in this study are as follows:

1. Vibration meter
2. The rubber belt plate
3. The rubber valve plate

3.5 Research Methodology

3.5.1 Preparation for vibration reduction sheet

Findings the rubber belt plate and the rubber valve plate by selecting each type of material from the same lot, batch and spec. Each material has different specification as follows:

3.5.1.1 Rubber belt plate

- Feature Elastomer rubber
- Feature Polyester-Polyamide carcass EP100 with 3 layers of Polyester

3.5.1.2 Rubber valve plate

- Feature Neoprene Rubber
- Feature JK-180-72-6 F Rubber

The rubber belt plate and the rubber valve plate were subjected for physical properties from dealer in the following areas:

- Thickness (mm.)
- Hardness (Shore) used standard ASTM D2240
- Tensile Strength (N/mm2) used standard DIN 53504
- Compression Set (%) used standard ASTM 395 (Method B)
- Abrasion (volume loss, mm^3) used standard DIN 53516

Cut the rubber belt plate and the rubber valve plate at different size based on weaving machine standard 240 mm. wide, 360 long and 10 mm. thickness, punching hole diameter 18.5 mm. before using as vibration reduction sheet as being shown in the following figure 3-1.

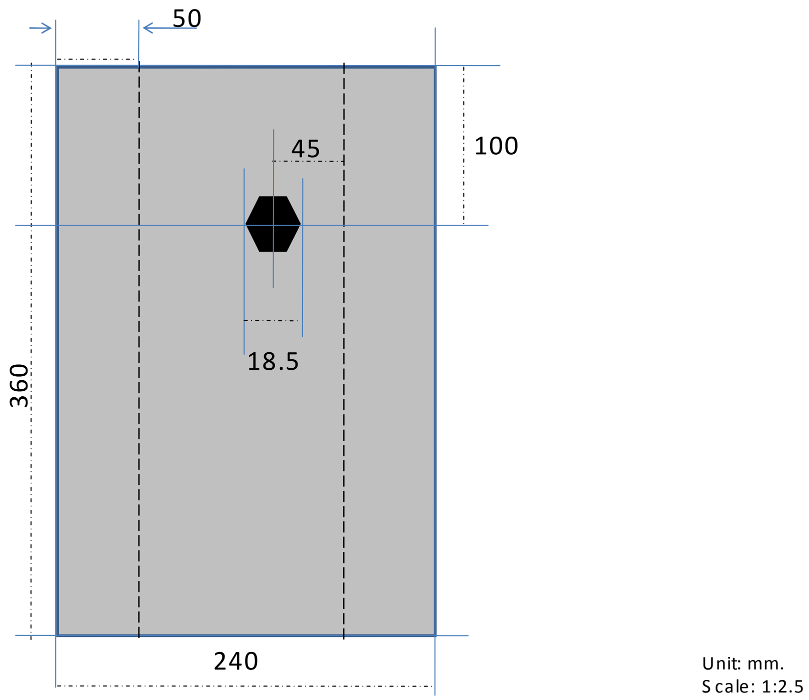


Figure 3-1 Preparations for Vibration Reduction Materials

3.5.2 Installation

Placing the rubber belt plate and the rubber valve plate from test weaving machine underneath the weaving machine pedestal through the following steps:

1. Place the sheet at the base of machine for all 4 legs on the concrete floor in a hole of machine base with the structure of building have foundation pile, that each the legs of machine for to separate structure the floor of the weaving machine with the structure of building as shown in the figure 3-2 and figure 3-3.

2. The vibration reduction materials 70 mm. wide and 10 mm. long to put in the side of machines surrounding their legs.

3. Attach the sheet at the base of machine using special glue for metal with Chemlok 205 and Chemlok 220 rubber sheets. Assemble the prepared sheets with the weaving machine using screw knot to attach machine legs firmly with the floor as shown in the figure 3-2 to figure 3-8.

4. Installing the vibration reduction material at the base of a machine by using the rubber belt plate in the first test and the rubber valve plate in the second test.

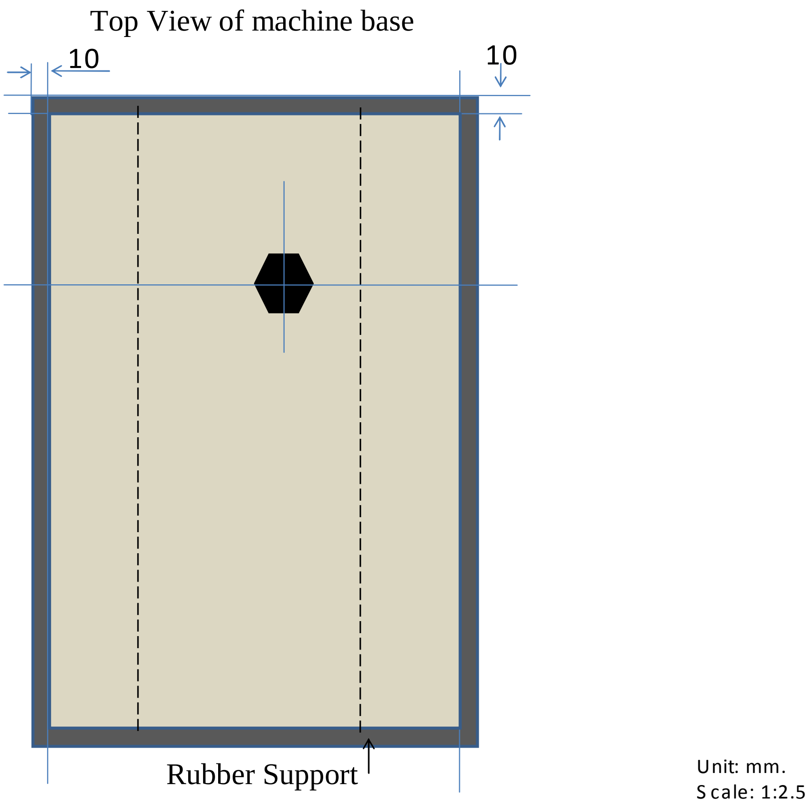


Figure 3-2 Installations of Vibration Reduction Materials (Top View)

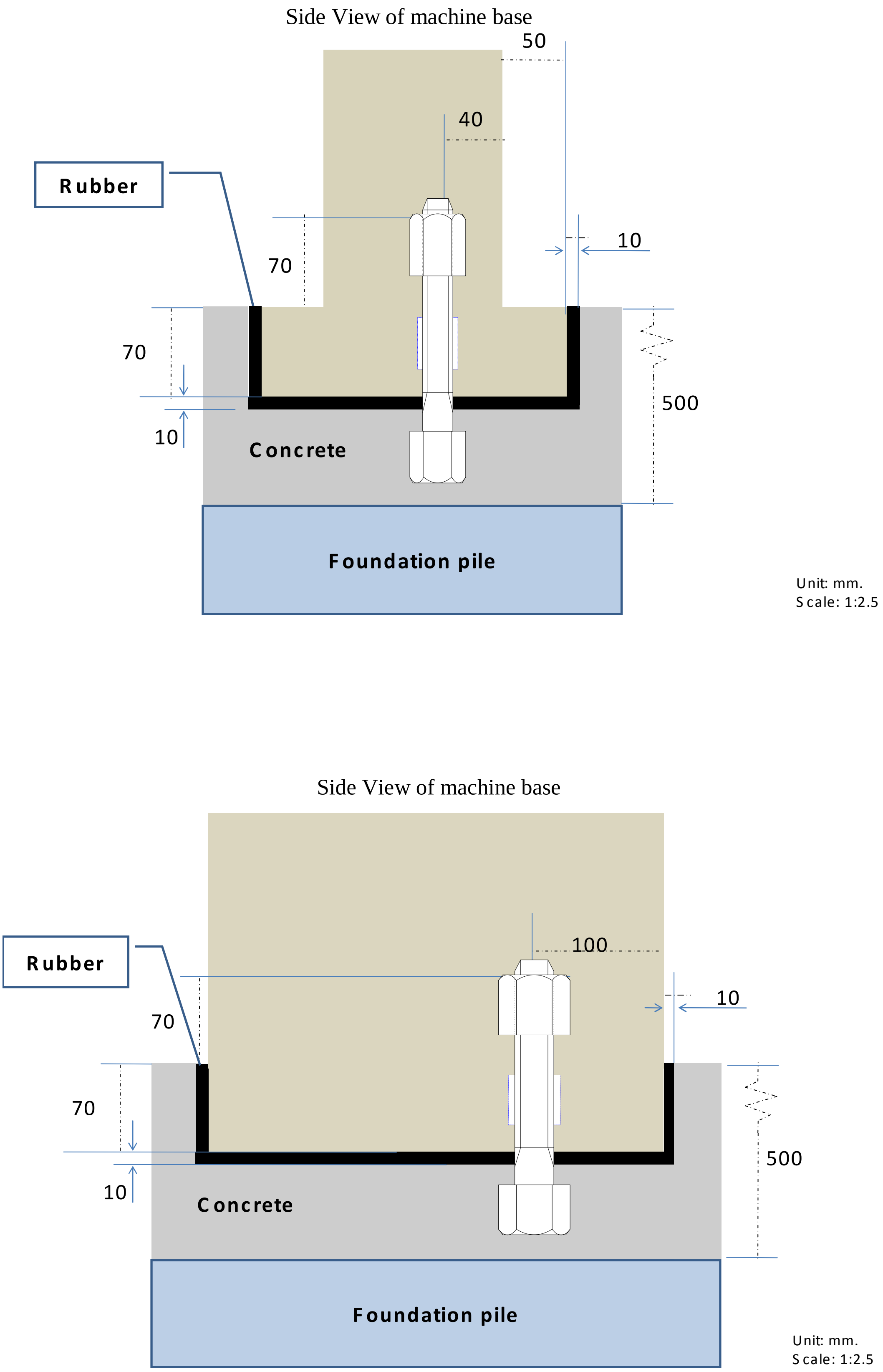


Figure 3-3 Installations of Vibration Reduction Materials (Side View)

Figure 3-4 The weaving machine

Figure 3-5 The behind of machine base before using the vibration reduction material

Figure 3-6 A side view of machine base before using the vibration reduction material

Figure 3-7 Installations the rubber belt plate at the machine base

Figure 3-8 Installations the rubber valve plate at the machine base

3.5.3 Measuring Vibration

In this study, vibration was measured along X, Y and Z axes at the legs of the weaving machine and the area surrounding the machine which was the vibration passing from the machine to the floor and affecting directly to the worker operating the machine. These were Personal Human Vibration meter model HAVPro Serial 03067 Calibration date 09/01/08. Placing transducer at the measuring point to read vibration which had given the value as Acceleration (m/s^2) through the following:

3.5.3.1 Measuring Machine Vibration

Determining the measuring point distance further from the machine legs 40 mm. Measuring point 1 and 2, and between 3 and 4 had the distance of 2306 mm. The distance of measuring point 1 and 4, and 2 to 3 were equaled to1279 mm. as illustrated in the figure 3-9.

1. Measuring vibration before using the vibration reduction material to support the machine base by measuring the vibration at all 4 legs at the determined points 5 times each point.

2. Following instruction in 3.5.2 for the rubber belt plate installation to measure vibration at the base of the machine at all 4 legs at the determined points 5 times each point.

3. Installing the rubber valve plate at the machine base as instructed in 3.5.2 by measuring vibration at the base of all 4 legs at the determine points 5 times.

3.5.3.2 Measuring Floor Vibration

Determining the measuring point at the floor around the machine, having the distance from the machine 300 mm. which was the distance for worker to stand working in front of the machine. And each point distance form each other 1153 mm. There are 6 points as be shown in figure 3-10.

1. Measuring vibration before using the vibration reduction material to support the machine base by measuring the vibration at all 6 determined points5 times.

2. Installing the rubber belt plate at the machine base as instructed in 3.5.2 by measuring vibration after placing the sheet at areas surrounding 6 determined points 5 times each point.

3. Installing the rubber valve plate at the machine base as instructed in 3.5.2 by measuring vibration at areas surrounding 6 determined points 5 times.

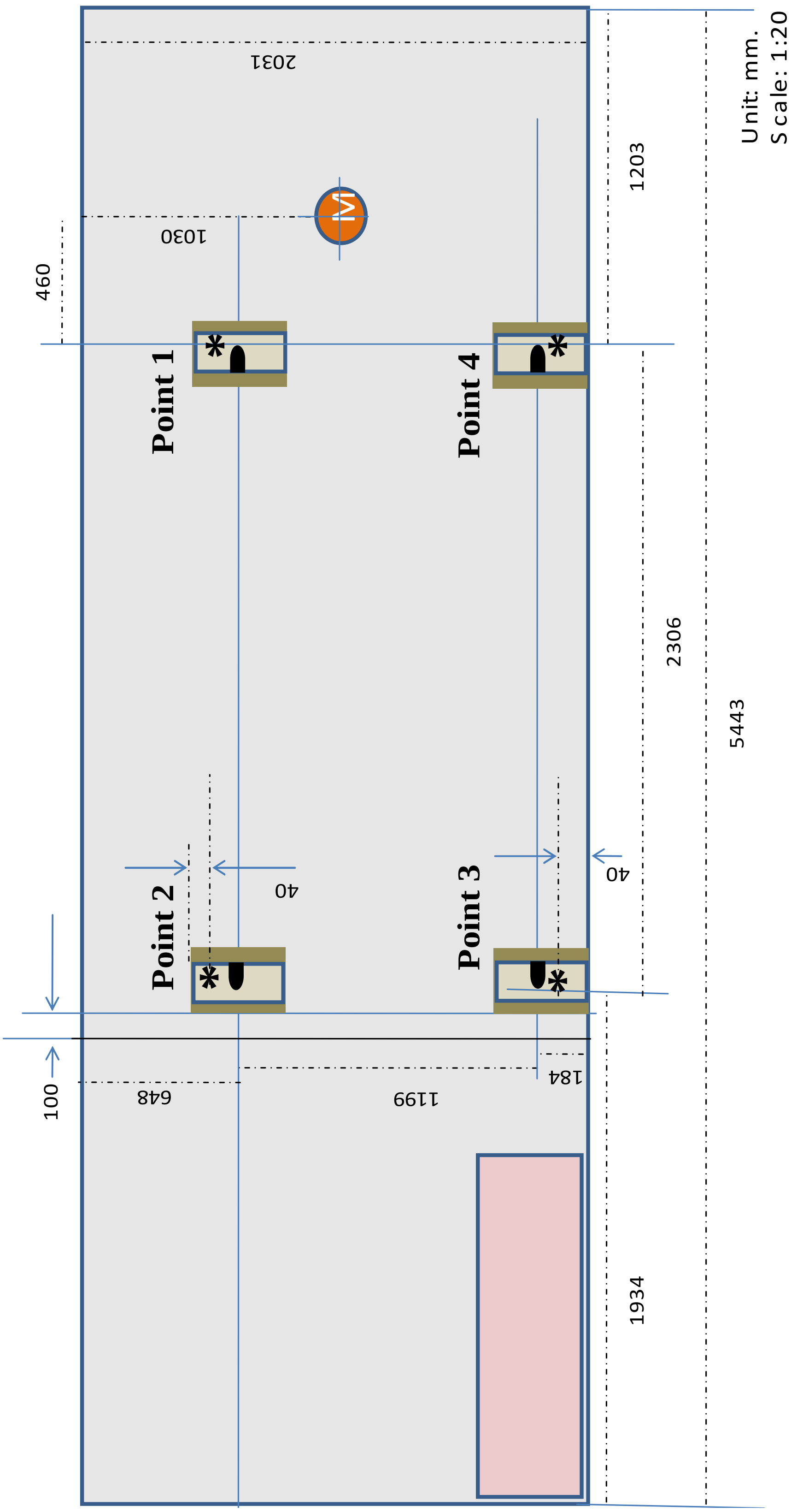


Figure 3-9 Point of measuring vibration at the machine

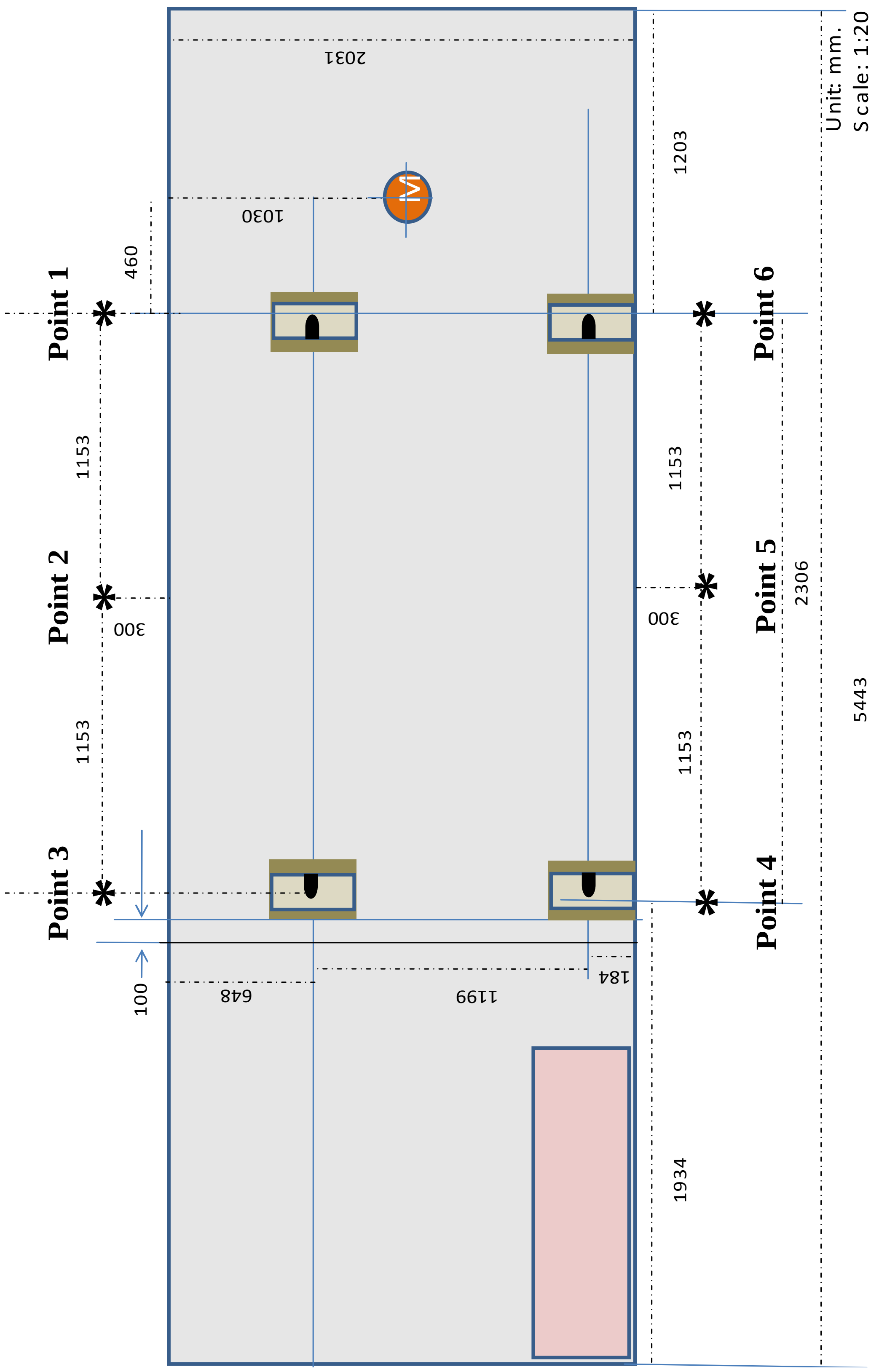


Figure 3-10 Point of measuring vibration around the machine location

3.6 Statistical Results Analysis

The data in this study were analyzed using following statistics:

3.6.1 Descriptive Statistics

To describe the characteristics and property of material and all measurements, mean ± S.D. was applied.

3.6.2 Inferential Statistics

3.6.2.1 The comparison of vibration between point of X, Y and Z axes and comparison of vibration between axis (X, Y and Z axes) at each point and total vibration before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate were tested by the Kruskal Wallis Test (χ^2-test) at 95% confident limit.

3.6.2.2 The comparison of vibration between before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate of Z axes at each point and total vibration were tested by the Kruskal Wallis Test (χ^2-test) at 95% confident limit.

3.6.2.3 The comparison between vibration at machine of Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate and vibration at floor of Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate were tested by Independent-Sample t-test at 95 % confident limit.

CHAPTER IV
RESULTS

The results are being presented as the follow:

4.1 Properties of material

4.2 Vibration Experimental Results at machine

4.2.1 Comparison of vibration at machine in each point before and after using the rubber belt plate and the rubber valve plate

4.2.2 Comparison of vibration at machine in each axis before and after using the rubber belt plate and the rubber valve plate

4.2.3 Comparison of vibration at machine before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration in Z axis

4.3 Vibration Experimental Results at floor

4.3.1 Comparison of vibration at floor in each point before and after using the rubber belt plate and the rubber valve plate

4.3.2 Comparison of vibration at floor in each axis before and after using the rubber belt plate and the rubber valve plate

4.3.3 Comparison of vibration at floor before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration in Z axis

4.4 Comparison of machine and floor vibration before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration in Z axis

4.5 Comparison in vibration reduction

4.1 Properties of material

The rubber belt plate and the rubber valve plate were physical properties by dealer in accordance with the standard measures. Hardness indicated that the strength of the rubber belt plate as 72.9 Shore A which was higher than the rubber valve plate with the strength of 68.1 Shore A. Tensile strength indicated that the rubber belt plate had tensile strength as equal as 18 N/mm^2 and the rubber valve plate with tensile strength 20 N/mm^2 which suggested the rubber valve plate was more ability to support tearing than the rubber belt plate.

Moreover, compression set indicated that the rubber belt plate had compression set as equal as 34.8 % and the rubber valve plate maintained compression set 32.6 % which suggested that the rubber valve plate could return to previous form after being compressed more than the rubber belt plate. Abrasion indicated that the rubber belt plate had abrasion as equal as 90 volume loss, mm^3 and the rubber valve plate had abrasion as equal as 150 volume loss, mm^3 which suggested that the rubber belt plate more lasting abrasion the rubber valve plate.

Table 4-1 Results from testing physical properties of the rubber belt plate and the rubber valve plate

Properties of material	The rubber belt plate	The rubber valve plate
Thickness (mm.)	10	10
Hardness (Shore A)	72.9	68.1
Tensile strength (N/mm^2)	18	20
Compression set (%)	34.8	32.6
Abrasion (volume loss, mm^3)	90	150

4.2 Vibration Experimental Results at machine

The experimental of vibration at machine measurement results were from x , y and z axis before using the rubber belt plate and the rubber valve plate as the vibration reducing materials by measuring vibration at all 4 legs of the machine 5 times for each point for the total vibration 20 times.

The highest vibration 3.6220 m/s^2 was measured at point 1 before using the vibration reducing material in Z axis and the lowest vibration 0.2581 m/s^2 at point 2 in Y axis derived from using the rubber valve plate to reduce vibration. Vibration happened in each axis is shown in the Appendix C.

The measurement results indicated different. Before using the vibration reducing materials, vibration measurement results range from 0.2270 to 1.0300, 0.1950 to 0.7750 and 0.5770 to 4.8700 m/s^2, the mean were 0.6086, 0.4606 and 2.3230 m/s^2 in X, Y and Z axis respectively. Vibration while using the rubber belt plate to reduce vibration were from 0.2250 to 1.0010, 0.2116 to 0.7027 and 0.5810 to 4.5520 m/s^2 with the Mean as equal as 0.5511, 0.4244 and 2.0764 m/s^2 in X, Y and Z axis respectively. Vibration while using the rubber valve plate as the vibration reducing material indicated value from 0.2155 to 0.9235, 0.2185 to 0.6982 and 0.5458 to 3.8120 m/s^2 with the Mean as equal as 0.5502, 0.4193 and 1.9456 m/s^2 in X, Y and Z axis , having the average vibration at each point being shown in Table 4-2.

Table 4-2 The vibration at machine of before using vibration reduction materials and after using different type of materials classified by axes X, Y and Z

	Axis X Mean ± S.D.	Axis Y Mean ± S.D.	Axis Z Mean ± S.D.
Before using vibration reduction materials			
Point 1			
Point 2	0.8278 ± 0.1617	0.6497 ± 0.1238	3.6220 ± 0.8352
Point 3	0.3679 ± 0.1896	0.2697 ± 0.0990	1.2089 ± 0.6152
Point 4	0.6265 ± 0.3376	0.4551 ± 0.2172	1.9677 ± 1.5770
Total	0.6122 ± 0.3420	0.4678 ± 0.2589	2.4936 ± 1.5397
	0.6086 ± 0.2994	0.4606 ± 0.2199	2.3230 ± 1.4355
Using the rubber belt plate as vibration reduction material			
Point 1	0.7731 ± 0.1393	0.5865 ± 0.0564	3.3337 ± 0.7449
Point 2	0.3405 ± 0.1464	0.2589 ± 0.0475	1.0893 ± 0.4663
Point 3	0.5723 ± 0.2802	0.4346 ± 0.1114	1.6821 ± 0.9071
Point 4	0.5186 ± 0.2977	0.4176 ± 0.1847	2.2006 ± 1.0365
Total	0.5511 ± 0.2623	0.4244 ± 0.1584	2.0764 ± 1.1311
Using the rubber valve plate as vibration reduction material			
Point 1	0.7008 ± 0.0928	0.5597 ± 0.0972	3.1525 ± 0.4184
Point 2	0.3528 ± 0.1845	0.2581 ± 0.0433	1.0622 ± 0.5088
Point 3	0.5797 ± 0.2904	0.4193 ± 0.1039	1.6762 ± 0.7056
Point 4	0.5674 ± 0.2963	0.4404 ± 0.0834	1.8913 ± 1.0166
Total	0.5502 ± 0.2485	0.4193 ± 0.1351	1.9456 ± 1.0111

4.2.1 Comparison of vibration at machine in each point before and after using the rubber belt plate and the rubber valve plate

After testing vibration at machine from each point of X, Y and Z axes acquired before using vibration reduction materials and during the use of the rubber belt plate and the rubber valve plate through test of Homogeneity of variance, findings indicated uneven variation with statistical significant p-value < 0.05. Non-parametric which had been used together with the application of Kruskal-Wallis test (χ^2-test) revealed vibration measured before and after using the rubber belt plate and the rubber valve plate as vibration reduction materials, having average vibration from each point of X, Y and Z axes acquired before using vibration reduction materials with statistical not significance different from X axis with p-value = 0.164, Y axis with p-value = 0.059 and Z axis with p-value = 0.063 and 95% reliability as being shown in Table 4-3.

Table 4-3 Comparison of vibration at machine between point of X, Y and Z axes before using vibration reduction materials

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Axis X						
Point 1	20	0.8278	0.1617	3,16	5.103	0.164
Point 2	20	0.3679	0.1896			
Point 3	20	0.6265	0.3376			
Point 4	20	0.6122	0.3420			
Axis Y						
Point 1	20	0.6497	0.1238	3,16	7.434	0.059
Point 2	20	0.2697	0.0990			
Point 3	20	0.4551	0.2172			
Point 4	20	0.4678	0.2589			
Axis Z						
Point 1	20	3.6220	0.8325	3,16	7.297	0.063
Point 2	20	1.2089	0.6152			
Point 3	20	1.9677	1.5770			
Point 4	20	2.4963	1.5397			

Average vibration from each point of X, Y and Z axes acquired after using the rubber belt plate had statistical significance different from X axis p-value = 0.063 but Y and Z axes had statistical significant differences, Y axis with p-value = 0.010 and Z axis with p-value = 0.010 and 95% reliability as being shown in Table 4-4.

Table 4-4 Comparison of vibration at machine between position of X, Y and Z axes after using the rubber belt plate

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Axis X						
Point 1	20	0.7731	0.1393	3,16	7.290	0.063
Point 2	20	0.3405	0.1464			
Point 3	20	0.5723	0.2802			
Point 4	20	0.5186	0.2977			
Axis Y						
Point 1	20	0.5865	0.0564	3,16	11.314	0.010
Point 2	20	0.2589	0.0475			
Point 3	20	0.4346	0.1114			
Point 4	20	0.4176	0.1847			
Axis Z						
Point 1	20	3.3337	0.7449	3,16	11.425	0.010
Point 2	20	1.0893	0.4663			
Point 3	20	1.6821	0.9071			
Point 4	20	2.0764	1.0365			

Average vibration from each point of X, Y and Z axes acquired after using the rubber valve plate had statistical significant not different from X axis p-value = 0.205 but Y and Z axes had statistical significant differences, Y axis p-value = 0.005 and Z axis p-value = 0.004 and 95% reliability as being shown in the Table 4-5.

Table 4-5 Comparison of vibration at machine between position of X, Y and Z axes after using the rubber valve plate to reduce vibration

	n	$\bar{x}$	SD	d.f.	χ^2-test	P-value
Axis X						
Point 1	20	0.7008	0.0928	3,16	4.589	0.205
Point 2	20	0.3528	0.1845			
Point 3	20	0.5797	0.2904			
Point 4	20	0.5674	0.2963			
Axis Y						
Point 1	20	0.5597	0.0972	3,16	12.989	0.005
Point 2	20	0.2581	0.0433			
Point 3	20	0.4193	0.1039			
Point 4	20	0.4404	0.0834			
Axis Z						
Point 1	20	3.1525	0.4184	3,16	13.129	0.004
Point 2	20	1.0662	0.5088			
Point 3	20	1.6762	0.7056			
Point 4	20	1.8913	1.0166			

4.2.2 Comparison of vibration at machine in each axis before and after using the rubber belt plate and the rubber valve plate

After testing vibration from average vibration at machine measured in X, Y and Z axes before using vibration reduction materials, during the use of the rubber belt plate and the rubber valve plate each point through Test of Homogeneity of variance, findings indicated uneven variation with statistical significant p-value < 0.05. Non-parametric which had been used together with the application of Kruskal-Wallis test (χ^2-test) revealed vibration from average vibration measured in X, Y and Z axes before using vibration reduction materials, during the use of the rubber belt plate and the rubber valve plate each point.

Findings after comparing differences from average vibration measured in X, Y and Z axes before using vibration reduction materials, during the use of the rubber belt plate and the rubber valve plate each point indicated that vibrations in X, Y and Z axes and all 4 points had no statistical significant differences. Only point 3 had vibration values before using the vibration reduction material along X, Y and Z with statistical significant differences at p-value = 0.121 as shown in Table 4-6toTable 4-9.

Table 4-6 Comparison of vibration at machine between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration (point 1)

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Before using vibration reduction materials						
- Axis X	5	0.8278	0.1617	2,12	10.220	0.006
- Axis Y	5	0.6497	0.1238			
- Axis Z	5	3.6220	0.8352			
Using the rubber belt plate as vibration reduction material						
- Axis X	5	0.7731	0.1393	2,12	11.180	0.004
- Axis Y	5	0.5865	0.0564			
- Axis Z	5	3.3337	0.7449			
Using the rubber valve plate as vibration reduction material						
- Axis X	5	0.7008	0.9277	2,12	11.580	0.003
- Axis Y	5	0.5597	0.0972			
- Axis Z	5	1.4710	0.4184			

Table 4-7 Comparison of vibration at machine between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration (point 2)

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Before using vibration reduction materials						
- Axis X	5	0.3679	0.1896	2,12	9.140	0.010
- Axis Y	5	0.2670	0.0990			
- Axis Z	5	1.2089	0.6152			
Using the rubber belt plate as vibration reduction material						
- Axis X	5	0.3405	0.1464	2,12	9.980	0.007
- Axis Y	5	0.2589	0.0475			
- Axis Z	5	1.0893	0.4663			
Using the rubber valve plate as vibration reduction material						
- Axis X	5	0.3528	0.1845	2,12	8.180	0.017
- Axis Y	5	0.2581	0.4330			
- Axis Z	5	1.0622	0.5088			

Table 4-8 Comparison of vibration at machine between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration (point 3)

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Before using vibration reduction materials						
- Axis X	5	0.6265	0.3376	2,12	4.220	0.121
- Axis Y	5	0.4551	0.2172			
- Axis Z	5	1.9677	1.5770			
Using the rubber belt plate as vibration reduction material						
- Axis X	5	0.5723	0.2802	2,12	7.760	0.021
- Axis Y	5	0.4346	0.1114			
- Axis Z	5	1.0164	0.9071			
Using the rubber valve plate as vibration reduction material						
- Axis X	5	0.5797	0.2904	2,12	9.620	0.008
- Axis Y	5	0.4193	0.1039	2,12		
- Axis Z	5	1.6762	0.7056	2,12		

Table 4-9 Comparison of vibration at machine between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration (point 4)

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Before using vibration reduction materials						
- Axis X	5	0.6122	0.3420	2,12	6.500	0.039
- Axis Y	5	0.4678	0.2589			
- Axis Z	5	2.4936	1.5397			
Using the rubber belt plate as vibration reduction material						
- Axis X	5	0.5186	0.2977	2,12	9.620	0.008
- Axis Y	5	0.4176	0.1847			
- Axis Z	5	2.2006	1.0365			
Using the rubber valve plate as vibration reduction material						
- Axis X	5	0.5674	0.2963	2,12	7.580	0.023
- Axis Y	5	0.4400	0.0834			
- Axis Z	5	1.8913	1.0166			

Findings after comparing differences from total average vibration at machine measured in X, Y and Z axes before using vibration reduction materials, during the use of the rubber belt plate and the rubber valve plate indicated that vibrations in X, Y and Z axes had statistical significant differences of p-value < 0.001 as shown in Table 4-10.

Table 4-10 Comparison of vibration at machine between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration (Total)

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Before using vibration reduction materials						
- Axis X	20	0.6086	0.2994	2,57	26.952	< 0.001
- Axis Y	20	0.4606	0.2199			
- Axis Z	20	2.3230	1.4355			
Using the rubber belt plate as vibration reduction material						
- Axis X	20	0.5511	0.2623	2,57	34.089	< 0.001
- Axis Y	20	0.4244	0.1584			
- Axis Z	20	2.0764	1.1311			
Using the rubber valve plate as vibration reduction material						
- Axis X	20	0.5502	0.2485	2,57	32.462	< 0.001
- Axis Y	20	0.4193	0.1351			
- Axis Z	20	1.9456	1.0111			

Measured vibration at machine before using the vibration reducing materials and during the use of different vibration reducing materials was expressed as the graph, it revealed that measured vibration in Z axis higher than value in X and Y axis before and after using the rubber belt plate to reduce vibration as shown in the Graph 4-1. Findings indicated measured vibration in Z axis before and after using the rubber belt plate and the rubber valve plate as equal as 2.3230, 2.0764 and 1.9456 m/s^2 respectively.

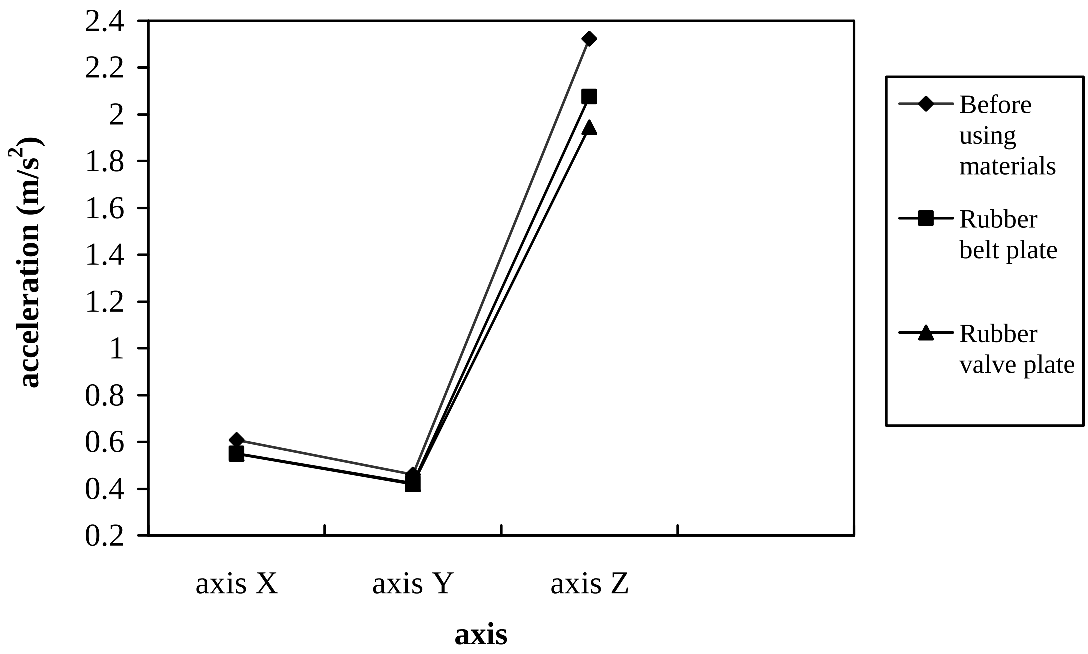


Figure 4-1 Comparison of average vibration at machine before using the vibration reducing materials and after using different types of material classified by X, Y and Z axis

4.2.3 Comparison of vibration at machine before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration in Z axis

After testing vibration at machine in Z axes acquired before using vibration reduction materials and during the use of the rubber belt plate and the rubber valve plate through Test of Homogeneity of variance, findings indicated uneven variation with statistical significant p-value < 0.05. Non-parametric which had been used together with the application of Kruskal-Wallis test revealed vibration measured before and after using the rubber belt plate and the rubber valve plate as vibration reduction materials, having average vibration for all points with no statistical significant differences at point 1 with p-value = 0.512, point 2 with p-value = 0.932, point with p-value = 0.932 and point 4 with p-value = 0.533 and 95% reliability as being shown in Table 4-11.

Table 4-11 Comparison of vibration at machine from Z axis before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration in each point

	n	$\bar{x}$	SD	df	χ^2-test	p-value
Point 1						
- Before using the vibration reducing materials	5	3.6220	0.8352	2,12	1.340	0.512
- Using the rubber belt plate as the vibration reducing material	5	3.3337	0.7449			
- Using the rubber valve plate as the vibration reducing material	5	3.1525	0.4184			
Point 2						
- Before using the vibration reducing materials	5	1.2089	0.6152	2,12	0.141	0.932
- Using the rubber belt plate as the vibration reducing material	5	1.0893	0.4663			
- Using the rubber valve plate as the vibration reducing material	5	1.0622	0.5088			
Point 3						
- Before using the vibration reducing materials	5	1.9677	1.5770	2,12	0.140	0.932
- Using the rubber belt plate as the vibration reducing material	5	1.6821	0.9071			
- Using the rubber valve plate as the vibration reducing material	5	1.6762	0.7056			

Table 4-11 Comparison of vibration at machine from Z axis before using vibration reduction materials and after using the Rubber belt plate and the Rubber valve plate to reduce vibration in each point (continued)

	n	x̄	SD	df	χ^2-test	p-value
Point 4						
- Before using the vibration reducing materials	5	2.4936	1.5397	2,12	1.260	0.533
- Using the rubber belt plate as the vibration reducing material	5	2.2006	1.0365			
- Using the rubber valve plate as the vibration reducing material	5	1.8913	1.0166			

Findings after comparing differences from total average vibration at machine from Z axis before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration indicated that vibrations in Z axes had no statistical significant differences with p-value = 0.650 and 95% reliability as being shown in Table 4-12.

Table 4-12 Comparison of total vibration at machine from Z axis before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration (Total)

	n	x̄	SD	df	χ^2-test	p-value
- Before using the vibration reducing materials	20	2.3230	1.4355	2,57	0.862	0.650
- Using the rubber belt plate as the vibration reducing material	20	2.0764	1.1311			
- Using the rubber valve plate as the vibration reducing material	20	1.9456	1.0111			

4.3 Vibration Experimental Results at floor

The experimental of vibration at floor measurement results were from X , Y and Z axis before using the rubber belt plate and the rubber valve plate as the vibration reducing materials by measuring vibration at 6 points on areas surrounding the machine 5 times each point for the total vibration values 30 times.

The measurement results indicated different. Before using the vibration reducing materials, vibration measurement results range from 0.0269 to 0.0306, 0.0266 to 0.0290 and 0.0506 to 0.0528 m/s^2, the mean were 0.0279, 0.0270 and 0.0513 m/s^2 in X, Y and Z axis respectively. Vibration while using the rubber belt plate to reduce vibration were from 0.0253 to 0.0270, 0.0242 to 0.0273 and 0.0340 to 0.0441 m/s^2 with the Mean as equal as 0.0261, 0.0256 and 0.0388 m/s^2 in X , Y and Z axis respectively. Vibration while using the rubber valve plate as the vibration reducing material indicated value from 0.0238 to 0.0291, 0.0238 to 0.0257 and 0.0238 to 0.0272 m/s^2 with the Mean as equal as 0.0245, 0.0240 and 0.0250 m/s^2 in X, Y and Z axis respectively as average vibration at each point being shown in Table 4-13.

Table 4-13 Vibration at the floor before using vibration reduction materials and after using different type of materials classified by axis X, Y and Z

	Axis X Mean ± S.D.	Axis Y Mean ± S.D.	Axis Z Mean ± S.D.
Before using vibration reduction materials			
Point 1	0.0288 ± 0.0016	0.0274 ± 0.0009	0.0517 ± 0.0007
Point 2	0.0271 ± 0.0002	0.0270 ± 0.0001	0.0515 ± 0.0005
Point 3	0.0272 ± 0.0005	0.0268 ± 0.0001	0.0515 ± 0.0005
Point 4	0.0283 ± 0.0003	0.0269 ± 0.0001	0.0511 ± 0.0002
Point 5	0.0275 ± 0.0007	0.0269 ± 0.0001	0.0512 ± 0.0002
Point 6	0.0283 ± 0.0013	0.0271 ± 0.0002	0.0509 ± 0.0002
Total	0.0280 ± 0.0010	0.0270 ± 0.0004	0.0513 ± 0.0005
Using the rubber belt plate as vibration reduction material			
Point 1	0.0266 ± 0.0003	0.0258 ± 0.0002	0.0388 ± 0.0049
Point 2	0.0258 ± 0.0002	0.0256 ± 0.0008	0.0389 ± 0.0015
Point 3	0.0259 ± 0.0002	0.0255 ± 0.0004	0.0387 ± 0.0007
Point 4	0.0262 ± 0.0001	0.0254 ± 0.0004	0.0391 ± 0.0010
Point 5	0.0258 ± 0.0004	0.0254 ± 0.0009	0.0388 ± 0.0023
Point 6	0.0262 ± 0.0002	0.0256 ± 0.0010	0.0385 ± 0.0003
Total	0.0261 ± 0.0003	0.0256 ± 0.0006	0.0388 ± 0.0021
Using the rubber valve plate as vibration reduction material			
Point 1	0.0253 ± 0.0022	0.0243 ± 0.0008	0.0255 ± 0.0014
Point 2	0.0240 ± 0.0001	0.0238 ± 0.0000	0.0253 ± 0.0014
Point 3	0.0240 ± 0.0001	0.0238 ± 0.0001	0.0250 ± 0.0012
Point 4	0.0249 ± 0.0016	0.0237 ± 0.0001	0.0250 ± 0.0006
Point 5	0.0247 ± 0.0005	0.0240 ± 0.0004	0.0247 ± 0.0013
Point 6	0.0247 ± 0.0008	0.0240 ± 0.0001	0.0250 ± 0.0011
Total	0.0245 ± 0.0012	0.0240 ± 0.0004	0.0250 ± 0.0011

4.3.1 Comparison of vibration at floor in each point before and after using the rubber belt plate and the rubber valve plate

After testing vibration at floor from each point of X, Y and Z axes acquired before using vibration reduction materials and during the use of the rubber belt plate and rubber valve plate through Test of Homogeneity of variance, findings indicated uneven variation with statistical significant p-value < 0.05. Non-parametric which had been used together with the application of Kruskal-Wallis test (χ^2-test) revealed vibration measured before and after using the rubber belt plate and the rubber valve plate as vibration reduction materials, having average vibration from each point of X and Y axes acquired before using vibration reduction materials with statistical significant differences, X axis with p-value = 0.037, Y axis with p-value = 0.040 but Z axis had no statistical significant differences from Y axes at p-value = 0.066 and 95% reliability as being shown in the Table 4-14.

Table 4-14 Comparison of vibration at floor between point of X, Y and Z axes before using vibration reduction materials

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Axis X						
Point 1	30	0.0288	0.0016	5,24	11.818	0.037
Point 2	30	0.0271	0.0002			
Point 3	30	0.0272	0.0005			
Point 4	30	0.0283	0.0003			
Point 5	30	0.0275	0.0007			
Point 6	30	0.0283	0.0013			
Axis Y						
Point 1	30	0.0274	0.0009	5,24	11.647	0.040
Point 2	30	0.0270	0.0001			
Point 3	30	0.0268	0.0001			
Point 4	30	0.0269	0.0001			
Point 5	30	0.0269	0.0001			
Point 6	30	0.0271	0.0002			
Axis Z						
Point 1	30	0.0517	0.0007	5,24	10.329	0.066
Point 2	30	0.0515	0.0005			
Point 3	30	0.0515	0.0005			
Point 4	30	0.0511	0.0002			
Point 5	30	0.0512	0.0002			
Point 6	30	0.0509	0.0002			

Average vibration from each point of X axes acquired after using the rubber belt plate with statistical significant differences, X axes p-value = 0.002 but Y and Z axes had no statistical significance different from Y axis with p-value = 0.827 and Z axis with p-value = 0.943 and 95% reliability as being shown in the Table 4-15.

Table 4-15 Comparison of vibration at floor between point of X, Y and Z axes after using the rubber belt plate

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Axis X						
Point 1	30	0.0266	0.0003	5,24	18.873	0.002
Point 2	30	0.0258	0.0002			
Point 3	30	0.0259	0.0002			
Point 4	30	0.0262	0.0001			
Point 5	30	0.0258	0.0004			
Point 6	30	0.0262	0.0002			
Axis Y						
Point 1	30	0.0258	0.0002	5,24	2.156	0.827
Point 2	30	0.0256	0.0008			
Point 3	30	0.0255	0.0004			
Point 4	30	0.0254	0.0004			
Point 5	30	0.0254	0.0009			
Point 6	30	0.0256	0.0010			
Axis Z						
Point 1	30	0.0388	0.0049	5,24	1.220	0.943
Point 2	30	0.0389	0.0015			
Point 3	30	0.0387	0.0007			
Point 4	30	0.0391	0.0010			
Point 5	30	0.0388	0.0023			
Point 6	30	0.0385	0.0003			

Average vibration from each point of X, Y and Z axes acquired after using the rubber valve plate with no statistical significance different from X axes at p-value = 0.813 ,Y axis at p-value = 0.084 and Z axis at p-value = 0.597 and 95% reliability as being shown in the Table 4-16.

Table 4-16 Comparison of vibration at floor between point of X, Y and Z axes after using the rubber valve plate

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Axis X						
Point 1	30	0.0253	0.0022	5,24	2.257	0.813
Point 2	30	0.0240	0.0001			
Point 3	30	0.0240	0.0001			
Point 4	30	0.0249	0.0016			
Point 5	30	0.0247	0.0005			
Point 6	30	0.0247	0.0008			
Axis Y						
Point 1	30	0.0243	0.0008	5,24	9.691	0.084
Point 2	30	0.0238	0.0000			
Point 3	30	0.0238	0.0001			
Point 4	30	0.0237	0.0001			
Point 5	30	0.0240	0.0004			
Point 6	30	0.0240	0.0001			
Axis Z						
Point 1	30	0.0255	0.0049	5,24	3.677	0.597
Point 2	30	0.0253	0.0015			
Point 3	30	0.0250	0.0007			
Point 4	30	0.0250	0.0010			
Point 5	30	0.0247	0.0023			
Point 6	30	0.0250	0.0003			

4.3.2 Comparison of vibration at floor in each axis before and after using the rubber belt plate and rubber valve plate

After testing vibration from average vibration at floor measured in X, Y and Z axes before using vibration reduction materials, during the use of the rubber belt plate and the rubber valve plate each point through test of Homogeneity of variance, findings indicated uneven variation with statistical significant p-value < 0.05. Non-parametric which had been used together with the application of Kruskal-Wallis test (χ^2-test) revealed vibration from average vibration measured in X, Y and Z axes before using vibration reduction materials, during the use of the rubber belt plate and the rubber valve plate each point.

Findings after comparing differences from average vibration measured in X, Y and Z axes before using vibration reduction materials, during the use of the rubber belt plate and the rubber valve plate each point indicated that all point of vibrations in X, Y and Z axes had no statistical significant differences, only vibration when using the rubber valve plate at point 1,5and 6, having vibration values at X,Y and Z axes with statistical significant differences with p-value = 0.164 as shown in Table 4-17 to Table 4-22.

Table 4-17 Comparison of vibration at floor between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration (point 1)

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Before using vibration reduction materials						
Axis X	5	0.0288	0.0016	2,12	10.770	0.005
Axis Y	5	0.0274	0.0009			
Axis Z	5	0.0517	0.0007			
Using the rubber belt plate as vibration reduction material						
Axis X	5	0.0266	0.0003	2,12	12.567	0.002
Axis Y	5	0.0258	0.0002			
Axis Z	5	0.0388	0.0050			
Using the rubber valve plate as vibration reduction material						
Axis X	5	0.0253	0.0022	2,12	3.616	0.164
Axis Y	5	0.0243	0.0008			
Axis Z	5	0.0255	0.0014			

Table 4-18 Comparison of vibration at floor between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration (point 2)

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Before using vibration reduction materials						
Axis X	5	0.0271	0.1896	2,12	10.255	0.006
Axis Y	5	0.0270	0.0990			
Axis Z	5	0.0515	0.6152			
Using the rubber belt plate as vibration reduction material						
Axis X	5	0.0258	0.1464	2,12	9.514	0.009
Axis Y	5	0.0256	0.0475			
Axis Z	5	0.0389	0.4663			
Using the rubber valve plate as vibration reduction material						
Axis X	5	0.0240	0.0001	2,12	12.374	0.002
Axis Y	5	0.0238	0.0000			
Axis Z	5	0.0253	0.0010			

Table 4-19 Comparison of vibration at floor between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration (point 3)

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Before using vibration reduction materials						
Axis X	5	0.0272	0.0005	2,12	12.410	0.002
Axis Y	5	0.0268	0.0001			
Axis Z	5	0.0515	0.0005			
Using the rubber belt plate as vibration reduction material						
Axis X	5	0.0259	0.0002	2,12	10.917	0.004
Axis Y	5	0.0255	0.0004			
Axis Z	5	0.0387	0.0007			
Using the rubber valve plate as vibration reduction material						
Axis X	5	0.0240	0.0001	2,12	11.385	0.003
Axis Y	5	0.0238	0.0000			
Axis Z	5	0.0248	0.0012			

Table 4-20 Comparison of vibration at floor between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration (point 4)

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Before using vibration reduction materials						
Axis X	5	0.0283	0.0003	2,12	12.590	0.002
Axis Y	5	0.0269	0.0001			
Axis Z	5	0.0511	0.0002			
Using the rubber belt plate as vibration reduction material						
Axis X	5	0.0262	0.0001	2,12	12.774	0.002
Axis Y	5	0.0254	0.0004			
Axis Z	5	0.0390	0.0010			
Using the rubber valve plate as vibration reduction material						
Axis X	5	0.0249	0.0016	2,12	7.609	0.022
Axis Y	5	0.0237	0.0001			
Axis Z	5	0.0249	0.0006			

Table 4-21 Comparison of vibration at floor between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration (point 5)

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Before using vibration reduction materials						
Axis X	5	0.0277	0.0006	2,12	11.667	0.003
Axis Y	5	0.0269	0.0001			
Axis Z	5	0.0512	0.0002			
Using the rubber belt plate as vibration reduction material						
Axis X	5	0.0258	0.0004	2,12	9.551	0.008
Axis Y	5	0.0254	0.0009			
Axis Z	5	0.0388	0.0023			
Using the rubber valve plate as vibration reduction material						
Axis X	5	0.0241	0.0005	2,12	1.465	0.481
Axis Y	5	0.0240	0.0004			
Axis Z	5	0.0247	0.0013			

Table 4-22 Comparison of vibration at floor between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration (point 6)

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Before using vibration reduction materials						
Axis X	5	0.0283	0.0013	2,12	12.343	0.002
Axis Y	5	0.0271	0.0002			
Axis Z	5	0.0509	0.0002			
Using the rubber belt plate as vibration reduction material						
Axis X	5	0.0262	0.0002	2,12	10.538	0.005
Axis Y	5	0.0256	0.0010			
Axis Z	5	0.0385	0.0003			
Using the rubber valve plate as vibration reduction material						
Axis X	5	0.0247	0.0008	2,12	5.048	0.080
Axis Y	5	0.0240	0.0001			
Axis Z	5	0.0250	0.0011			

Findings after comparing differences from total average vibration at floor measured in X, Y and Z axes before using vibration reduction materials, during the use of the rubber belt plate and the rubber valve plate indicated that vibrations in X, Y and Z axes had statistical significant differences of p-value < 0.001 as shown in Table 4-23.

Table 4-23 Comparison of vibration at floor between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration (Total)

	n	$\bar{x}$	SD	d.f.	χ^2-test	p-value
Before using vibration reduction materials						
Axis X	5	0.0283	0.0013	2,12	69.497	< 0.001
Axis Y	5	0.0271	0.0002			
Axis Z	5	0.0509	0.0002			
Using the rubber belt plate as vibration reduction material						
Axis X	5	0.0262	0.0002	2,12	67.139	< 0.001
Axis Y	5	0.0256	0.0010			
Axis Z	5	0.0385	0.0003			
Using the rubber valve plate as vibration reduction material						
Axis X	5	0.0247	0.0008	2,12	35.933	< 0.001
Axis Y	5	0.0240	0.0001			
Axis Z	5	0.0250	0.0011			

Measured vibration before using the vibration reducing materials and during the use of different vibration reducing materials was expressed as the graph, it revealed that measured vibration in Z axis higher than value in X and Y axis before and after using the rubber belt plate to reduce vibration as shown in the Graph 4-2. Findings indicated measured vibration in Z axis before and after using the rubber belt plate and the rubber valve plate as equal as 0.0513, 0.0388 and 0.0250 m/s^2 respectively.

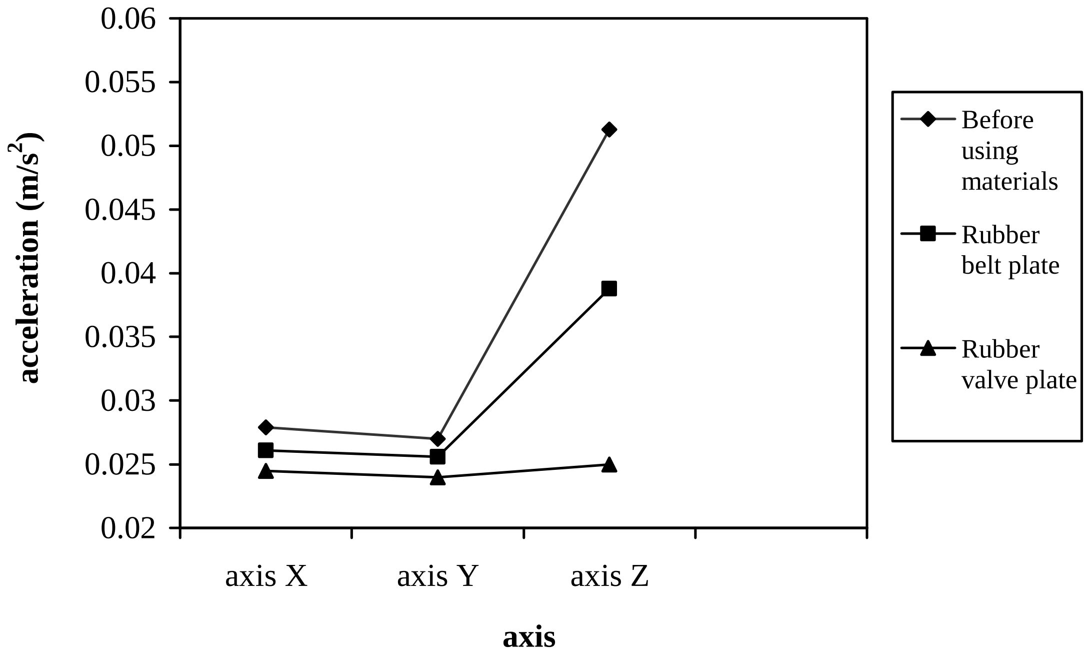


Figure 4-2 Comparison of average vibration at floor before using the vibration reducing materials and after using different types of material classified by X, Y and Z axis

4.3.3 Comparison of vibration at floor before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration in Z axis

After testing vibration from X, Y and Z axes acquired before using vibration reduction materials and during the use of the rubber belt plate and the rubber valve plate through Test of Homogeneity of variance, findings indicated uneven variation with statistical significant p-value < 0.05. Non-parametric which had been used together with the application of Kruskal-Wallis test (χ^2-test)revealed vibration measured before and after using the rubber belt plate and the rubber valve plate as vibration reduction materials, having average vibration all points (point 1 to 6) with statistical significant differences at p-value = 0.002 and 95% reliability as being shown in Table 4-24.

Table 4-24 Comparison of vibration at floor from Z axis before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration in each point

	n	$\bar{x}$	SD	df	χ^2-test	p-value
Point 1						
- Before using the vibration reducing materials	5	0.0255	0.0014	2,12	12.522	0.002
- Using the rubber belt plate as the vibration reducing material	5	0.0388	0.0049			
- Using the rubber valve plate as the vibration reducing material	5	0.0255	0.0014			
Point 2						
- Before using the vibration reducing materials	5	0.0515	0.0005	2,12	12.545	0.002
- Using the rubber belt plate as the vibration reducing material	5	0.0389	0.0015			
- Using the rubber valve plate as the vibration reducing material	5	0.0253	0.0014			
Point 3						
- Before using the vibration reducing materials	5	0.0515	0.0005	2,12	12.545	0.002
- Using the rubber belt plate as the vibration reducing material	5	0.0387	0.0007			
- Using the rubber valve plate as the vibration reducing material	5	0.0248	0.0012			

Table 4-24 Comparison of vibration at floor from Z axis before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration in each point (continued)

	n	$\bar{x}$	SD	df	χ^2-test	p-value
Point 4						
- Before using the vibration reducing materials	5	0.0511	0.0002	2,12	12.567	0.002
- Using the rubber belt plate as the vibration reducing material	5	0.0391	0.0010			
- Using the rubber valve plate as the vibration reducing material	5	0.0249	0.0006			
Point 5						
- Before using the vibration reducing materials	5	0.0512	0.0002	2,12	12.613	0.002
- Using the rubber belt plate as the vibration reducing material	5	0.0388	0.0023			
- Using the rubber valve plate as the vibration reducing material	5	0.0247	0.0013			
Point 6						
- Before using the vibration reducing materials	5	0.0509	0.0002	2,12	12.567	0.002
- Using the rubber belt plate as the vibration reducing material	5	0.0385	0.0003			
- Using the rubber valve plate as the vibration reducing material	5	0.0250	0.0011			

Findings after comparing differences from total average vibration at machine from Z axis before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration indicated that vibrations in Z axis had statistical significant differences at p-value < 0.001 and 95% reliability as being shown in Table 4-25.

Table 4-25 Comparison of total vibration at machine from Z axis before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration

	$\bar{x}$	SD	n	df	χ^2-test	p-value
- Before using the vibration reducing materials	2.3230	1.4355	20	2,57	79.287	< 0.001
- Using the rubber belt plate as the vibration reducing material	2.0764	1.1311	20			
- Using the rubber valve plate as the vibration reducing material	1.9456	1.0111	20			

4.4 Comparison of vibration machine and floor before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration in Z axis

After comparing vibration in Z axis measured from the machine and floor with t-test, findings indicated that vibration in Z axis had statistical significant differences at p-value < 0.001 as being shown in Table 4-26, both before and after using the rubber belt plate and the rubber valve plate to reduce vibration.

Table 4-26 Comparison of vibration machine and floor before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration in Z axis

	n	$\bar{x}$	SD	d.f.	t-test	p-value
Before using vibration reduction materials						
Machine	20	2.3230	1.4352	48	7.083	< 0.001
Floor	30	0.0513	0.0005			
Using the rubber belt plate as vibration reduction material						
Machine	20	2.0764	1.1311	48	7.589	< 0.001
Floor	30	0.0388	0.0021			
Using the rubber valve plate as vibration reduction material						
Machine	20	1.9450	1.0111	48	8.004	< 0.001
Floor	30	0.0250	0.0011			

The measurement results of total average vibration at machine and floor before using vibration reduction materials in Z axis were 2.3230 and 0.0513 m/s^2 respectively. Vibration while using the rubber belt plate in Z axis was 2.0764 and 0.0388 m/s^2 respectively. Vibrations while using the rubber valve plate in Z axis were 1.9450 and 0.0250 m/s^2, respectively. Findings after comparison in differences, total average vibration from Z axis at machine was higher than total average vibration from Z axis at the surrounding floor before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration.

Findings from the comparison of average vibration measured at the machine and the floor before and after using the rubber belt plate indicate that the building structure of machine have foundation pile at each the legs of machine could be absorb vibration transsferred from the machine to the floor acquired before using vibration reduction materials as 97.79 % and after using the rubber belt plate and the rubber valve plate could be increase absorb vibration transferred from the machine to the floor as 98.13 %, 98.71 % respectively. Before using the vibration reduction materials the floor receives the vibration from the machine was at 2.21 %. After using of the rubber belt plate and the rubber valve plate the floor receives the vibration from the machine was 1.87 % and 1.28 % respectively as shown in Table 4-27.

Table 4-27 Comparison of average vibration transferred from the machine to the floor using vibration reduction materials and after using the rubber belt plate and rubber valve plate to reduce vibration in Z axis

	Average vibration (m/s^2)		Absorbtion vibration of structure (%)	The floor receives the vibration from the machine (%)
	Machine	Floor		
Before using vibration reduction materials	2.3230	0.0513	97.79	2.21
Using the rubber belt plate as vibration reduction material	2.0764	0.0388	98.13	1.87
Using the rubber valve plate as vibration reduction material	1.9450	0.0250	98.71	1.28

4.5 Comparison in vibration reduction

Findings from the comparison of average vibration measured at machine before and after using the rubber belt plate indicated that it reduced vibration all points. The rubber belt plate reduced vibration for 7.96 %, 9.89 %, 14.51 %and 11.75 % in point 1 to 4, respectively which indicated that average values combined were able to reduce vibration as much as 10.62 %. Comparison of average vibration measured at machine before and after using the rubber valve plate indicated that it could reduce vibration at all points. The rubber valve plate reduced 12.96 %, 12.13 %, 14.81 % and 24.15 % in point 1 to 4, respectively. By average, all points combined could reduce vibration as much as 16.25 percent as shown in Table 4-28.

Table 4-28 Comparison of average vibration reduction at machine after using the rubber belt plate and the rubber valve plate as the vibration reducing material in Z axis

Point	Vibration before use material (m/s^2)	Vibration after use material (m/s^2)		Vibration reduction (%)	
		The rubber belt plate	The rubber valve plate	The rubber belt plate	The rubber valve plate
1	3.6220	3.3337	3.1526	7.96	12.96
2	1.0209	1.0893	1.0622	9.89	12.13
3	1.9677	1.6821	1.6762	14.51	14.81
4	2.4936	2.2001	1.8913	11.75	24.15
Total	2.3230	2.0764	1.9456	10.62	16.25

Findings from the comparison of average vibration measured at machine before and after using the rubber belt plate indicated that it reduced vibration at all points. The rubber belt plate could reduce vibration up to 25.05 %, 24.59 %, 24.94 %, 23.55 %, 24.29 %and 24.24 % in point 1 to 6, respectively. By average, all points combined could reduce vibration as much as 24.45 %. Comparison of average vibration measured at machine before and after using the rubber valve plate indicated that it reduced vibration at all points.

The rubber valve plate could reduce vibration up to 50.64 %, 50.81 %, 51.78 %, 51.17 %, 51.81 % and 50.88 % in point 1 to 6, respectively. By average, all points combined could reduce vibration as much as 51.18 % as shown in Table 4-29.

Table 4-29 Comparison of average vibration reduction at floor after using the rubber belt plate and the rubber valve plate as the vibration reducing material in Z axis

Point	Vibration before use material (m/s^2)	Vibration after use material (m/s^2)		Vibration reduction (%)	
		The rubber belt plate	The rubber valve plate	The rubber belt plate	The rubber valve plate
1	0.0517	0.0388	0.0255	25.05	50.64
2	0.0516	0.0389	0.0253	24.59	50.81
3	0.0516	0.0387	0.0248	24.94	51.78
4	0.0511	0.0390	0.0250	23.55	51.17
5	0.0512	0.0388	0.0247	24.29	51.81
6	0.0509	0.0385	0.0250	24.24	50.88
Total	0.0513	0.0388	0.0250	24.45	51.18

Findings from the comparison of average vibration measured at machine before and after using the rubber belt plate and rubber valve plate indicated that the rubber valve plate reduced more vibration than using the rubber belt plate 5.63 %.

Findings from the comparison of average vibration measured at floor before and after using the rubber belt plate and the rubber valve plate indicated that the rubber valve plate reduced more vibration than using the rubber belt plate 26.73 %.

CHAPTER V
DISCUSSION

5.1 Results Discussions

5.1.1 Vibration Measured from the Machine

Measuring machine vibration indicated the following results:

1. Vibration in each axis, point 1-4 in X axis, point 1-4 in Y axis, point 1-4 in Z axis, before using the rubber belt plate and the rubber valve plate. Findings no differences in statistical significance, comparison results in Table 4-3, perhaps from the average vibration in each point of the same axis has nearly the same value and gone in the same direction.

2. After using the rubber belt plate, it is found that vibrations measured at X axis of point 1 to 4 had no differences and opposite at point 1 to 4 of Y and Z axes, results comparison in Table 4-4. Findings are similar with the use of the rubber valve plate, results comparison in Table 4-5. Overall results had been explained in Table 4.2 with similar average vibration in X axis before and after the use of the rubber belt plate and the rubber valve plate, but average vibration in Y and Z axes showed differences. Therefore, all 4 points in X axis show no differences in vibration while vibration in Y and Z both is different.

3. After comparing vibration in each point in all 3 axes, point 1 of X, Y and Z, before and after the use of the rubber belt plate and the rubber valve plate, it is found that vibration at each point in each axis before and after using vibration reduction materials revealed statistical significant differences ($p\text{-value} < 0.05$) with the exception at point 3 where there is no difference before using such materials ($p\text{-value} = 0.121$), results comparison in Table 4-6 to 4-9, perhaps the vibration from the thread spinning machine made the measured vibration indifferent. However, after using vibration reduction material made from the rubber, results in axes are different.

4. After comparing vibration in each point in each axis, from point 1 to 4 in X, Y and Z axes, before and after the use of the rubber belt plate and the rubber valve plate, findings reveal statistical significant differences in each point (p-value < 0.05), results comparison in Table 4-10, which gives the indications of dissimilar vibration values in X, Y and Z axes before and after using vibration reduction materials, perhaps from measuring vibration at different machine locations.

5. After judging vibration in Z axis and making comparison in each and every points before and after the use of the rubber belt plate and the rubber valve plate, results comparison in Table 4-11 and 4-12. The findings showed no statistical significant differences (p-value > 0.05) which indicated that the use of the rubber belt plate and the rubber valve plate was unable to reduce machine vibration or reduce only minimal vibration along Z axis judging from vibration values derived before and after using the materials. However, judging the average vibration measured at Z axis, findings suggested that the rubber valve plate could reduce more vibration than the rubber belt plate.

6. As seen in figure 4-1 the findings suggested the highest acceleration in X, Y and Z axes before using the vibration reduction materials. Next, the rubber belt plate and the rubber valve plate, respectively, suggest the ability of the rubber valve plate to reduce the most vibration from having the least acceleration.

5.1.2 Vibration Measured at the Floor

Findings derived from vibration measured at the floor appear as follows:

1. Results from measuring vibration in each point along each axis, point 1-6 in X, Y and Z axes, before using the rubber belt plate and the rubber valve plate indicated statistical significant differences in X and Y axes (p-value > 0.05). As for vibration in Z axis, there is no difference, comparison results in Table 4.14, perhaps vibration that passed from machine to the floor more is more at X and Y axes (horizontal vibration) than Z axis (vertical vibration).

2. The vibrations measured at points 1 to 6 of X axis are different after using the rubber belt plate, but the vibration measured at points 1 to 6 of Y and Z axes are indifferent, results comparison in Table 4-15. From this indication, using the

rubber belt plate can reduce vibration in X axis or front and back roll as well, and the vibrations measured at point 1 to 6 along X, Y and Z axes are indifferent, results comparison in Table 4-16, the rubber valve plate can reduce only minimal vertical and horizontal vibrations, in X, Y and Z axes.

3. After comparing vibrations in all 3 axes in each point (point 1 X, Y and Z axes) before and after the use of the rubber belt plate, findings indicate the vibrations with statistical significant differences (p-value < 0.05), except at point 1,4-6 which suggest no differences (p-value > 0.05), results comparison in Table 4-17 to 4-22, perhaps from using the rubber valve plate, the vibration reduction values from all three axes are not different and without statistical significant differences. However, the study still reveals other differences in the vibration.

4. After comparing vibrations of all points in each axis, point 1-6 in X, Y and Z axes, before and after the use of the rubber belt plate and the rubber valve plate, findings indicate the vibration with statistical significant differences (p-value < 0.05), results comparison in Table 4-23, perhaps from using the rubber belt plate and the rubber valve plate, the vibration reduction values are lower. In another words, judging from the average vibration in Table 4-23, the vibrations in X, Y and Z axes are higher before the use of vibration reduction materials

5. After comparing vibrations in all 3 axes in each point (point 1 in X, Y and Z axes) before and after the use of the rubber belt plate and the rubber valve plate, findings indicate the vibrations with statistical significant differences (p-value < 0.05), results comparison in Table 4-24 to 4-25, and the use of the rubber belt plate and the rubber valve plate at the machine base can help to reduce the vibrations. Judging from the average vibration measured at Z axis, the rubber valve plate can reduce more vibrations than the rubber belt plate.

6. Judging the acceleration from figure 4-2, findings indicate that the acceleration in X, Y and Z before using vibration reduction material has the highest value, next, the rubber belt plate and the rubber valve plate, respectively, which suggests that the use of the rubber valve plate can reduce the most vibration due to the lowest acceleration, thus, giving similar results as the acceleration measured at the machine.

5.1.3 Vibrations Measured from the Machine and the Floor

Findings from the vibrations measured at the machine and the floor in Z axis before and after the use of the rubber belt plate and the rubber valve plate suggest the vibration with statistical significant differences (p-value < 0.001), results comparison in Table 4-26. Also, from the graph showing the relationship between acceleration in each axis (figure 4-1 and 4-2), the rubber valve plate has less acceleration than the rubber belt plate before the use of materials. Judging from reduction percentage at the machine and the floor in Table 4-28 and Table 4-29, it indicates higher reduction percentage from the use of the rubber valve plate than the rubber belt plate.

The results indicate that the building structure of machine have foundation pile at each the legs of machine could be absorb vibration transsferred from the machine to the floor. To explain further, before using the vibration reduction materials vibration transmitted from the machine to the floor was as 97.79 percent and after using the rubber belt plate and the rubber valve plate could be increase absorb vibration transferred from the machine to the floor was as 98.13 percent, 98.71 percent respectively in Table 4-27. Before using the vibration reduction materials the floor receives the vibration from the machine was at 2.21 percent, after the use of such materials, the vibration had been reduced. With the use of the rubber belt plate and the rubber valve plate the floor receives the vibration from the machine was 1.87 percent and 1.28 percent. It is found that the rubber belt plate and the rubber valve plate both have the elasticity and ability to absorb vibration, but they are unable to withstand high temperature and less durable. With less damping factor, vibration reduction can be more effective. As for the machine frequency at 14.25 Hz (J.C. Snowdon), neoprene pads which is the same synthesis rubber as the rubber valve can withstand the force in vertical direction well and reduce damages from severe vibration (Semih S.Tezcan and Ahmet Civi).

Judging from the graph figure 2-16 (16) where the machine frequency is equaled to 14.25 Hz, velocity = 855 rpm and the effectiveness in vibration reduction at the floor from using the rubber valve plate 51.18 percent, it suggests that the normal frequency of the material is about 8 Hz. If the material has normal frequency less than 8 Hz, the vibration can be reduced more effectively. This graph recommends vibration reduction effectiveness over 50 percent. However, the effectiveness of vibration reduction from the use of the rubber belt plate in this study is 24.45 percent, lower than using the rubber valve plate, perhaps the normal frequency of the rubber belt plate may be too high which decreased the ability to reduce vibration. Another possible reason is the rubber belt plate that is harder than the rubber valve plate may be too hard for making vibration reduction material for the machine under the study. Somehow, testing physical properties of the material reveals the ability of the rubber valve plate to resist more tear and wear than the rubber belt plate. The rubber valve plate can withstand more compression than the rubber belt plate. When being crushed by the weight, it can return to former shape without damages. Besides, the quantities of the rubber valve plate and rubber belt plate are different for the former contains 100 percent rubber while the latter only 60 percent per sample because the rubber belt plate mixed with polyester fibers which caused less elasticity than the rubber valve plate.

Even though the vibrations measured from the machine and the floor are not exceeded beyond the standard that could harm the machine and human, but average vibration measured more than fifty percent of alert, fit persons can just detect a vibration with perception threshold is approximately 0.015 m/s^2. Exposure it for lengthy period may create nuisance that can effect concentration and work efficiency. In the condition where a machine has been transformed, machine vibration may increase even further, resulting more vibration transmitted to the floor. Therefore, supporting the machine base with the vibration reduction materials can prevent vibration from the machine to the floor.

Then, results of this study support the use of the rubber valve plate at the base of the machine to reduce machine vibration and vibration passing from the machine better than using the rubber belt plate or not using any materials.

5.2 Limitations of the study

In the study, there are few limitations as follows:

5.1.1 Limitation of Tools

Vibration measured by Vibration Meter is expressed as RMS from determining Frequency whetting in each phase made it unable to differentiate the existing frequency. To conduct the diagnostics or determine duration for acceptable TLV, one must engage the tool that can separate frequency at 1-80 Hz (ISO 2631-1978).

5.1.2 Limitation of Materials Analysis

Finding effectiveness in the reduction of machine vibration requires knowing normal frequency of material which generally derived from finding Sub-Tangent to calculate normal frequency. During the study, it was discovered that Sub-Tangent analysis can perform in the Laboratory. Therefore, this study used the vibration reduction percentage from the experiment to find the normal frequency (namely, the rubber belt plate and the rubber valve plate) from figure 2-17.

5.1.3 Limitation of Measuring

In this study, machine vibration was measured both before and after the use of vibration reduction materials, normal machine operated, even with the difficulty in stopping the machine and placing materials to support the machine without waiting for all machines to stop working. Then, the experiment was done with one machine only by selecting a machine with same made and features, same installation, motor power, velocity, machine size, made and model.

CHAPTER VI
CONCLUSION AND RECOMMENDATION

6.1 Conclusions

The purpose of this study was to compare vibration reduction materials to support weaving machine base in the Textile Factory In this study, materials such as the rubber belt plate and the rubber valve plate were used.

6.1.1 Vibration Measured from the Machine

Findings from the experiment indicated the results:

1. The highest vibration measured at machine in this study before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration was 4.8700 m/s^2, 4.5520 m/s^2 and 3.8120 m/s^2 respectively in Z axis. After the comparison with graph figure 2-6, vibration as velocity yielded 2.0-2.5 mm/s. Since the machine under the study had the power of 37 kW, the machine was classified as Class II. After the comparison with Table 2-1, it was found that the vibration measured at Zone B represented normal vibration for the machine to continue working without scheduling the maintenance.

2. Vibration at machine between point before using vibration reduction materials revealed statistical not significant differences at p-value = 0.164, 0.059 and 0.063 and 95 percent reliability of X, Y and Z axes respectively.

3. Vibration at machine between point after using the rubber belt plate to reduce vibration in X axes revealed statistical not significant differences at p-value = 0.063 but Y and Z axes revealed statistical significant differences at p-value = 0.010 and 95 percent reliability.

4. Vibration at machine between point after using the rubber valve plate to reduce vibration in X axes revealed statistical not significant differences at p-value = 0.205 but Y and Z axes revealed statistical significant differences at p-value = 0.005 and p-value = 0.004 respectively and 95 percent reliability.

5. Vibration at machine between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration revealed not differences all point intense at Z axis with more average vibration than X and Y axis.

6. Vibration measured in Z axis at machine before using the vibration reducing materials and after using the rubber belt plate and the rubber valve plate revealed not differences all point. Total values vibration statistical not significant differences at p-value = 0.650 and 95 percent reliability.

7. Average vibration measured at machine before and after using the rubber belt plate and the rubber valve plate indicated that the rubber valve plate and the rubber belt plate reduction have average vibration less than before using the vibration reducing materials.

6.1.2 Vibration Measured at the Floor

Findings from the experiment indicated the results:

1. The highest vibration measured in this at floor in this study before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration was 0.0528 m/s^2, 0.0441 m/s^2 in Z axis and 0.0291 m/s^2 in X axis respectively. Average vibration measured more than fifty percent of alert, fit persons can just detect a vibration with perception threshold is approximately 0.015 m/s^2 but less than 0.315 m/s^2 that value of not uncomfortable with recommendation of ISO 2631.

2. Vibration at floor between point before using vibration reduction materials in Y and Z axes revealed statistical significant differences at p-value = 0.037 and 0.040 respectively but Z axes revealed statistical not significant differences at p-value = 0.066 and 95 percent reliability.

3. Vibration at floor between point after using the rubber belt plate to reduce vibration in X axes revealed statistical significant differences at p-value = 0.002 but Y and Z axes revealed not statistical significant differences at p-value = 0.827 and 0.943 respectively and 95 percent reliability.

4. Vibration at floor between point after using the rubber valve plate to reduce vibration revealed statistical not significant differences at p-value = 0.813, 0.084 and 0.597 and 95 percent reliability of X, Y and Z axes respectively.

5. Vibration at floor between X, Y and Z axes before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration revealed differences all point. After using the rubber valve plate to reduce vibration at point 2 in X, Y and Z revealed differences is intense at Z axis with more average vibration than X and Y axis.

6. Vibration measured in Z axis at floor before using the vibration reducing materials and after using the rubber belt plate and the rubber valve plate revealed differences all point. Total values vibration statistical significant differences at p-value < 0.001 and 95 percent reliability.

7. Average vibration measured at floor before and after using the rubber belt plate and the rubber valve plate indicated that the rubber valve plate and the rubber belt plate reduction have average vibration less than before using the vibration reducing materials.

6.1.3 Vibrations Measured from the Machine and the Floor

Findings from the experiment indicated the results:

1. Total average vibration from Z axis at machine higher than total average vibration from Z axis at floor all aver before using vibration reduction materials and after using the rubber belt plate and the rubber valve plate to reduce vibration statistical significant differences at p-value < 0.001 and 95 percent reliability.

2. Before using vibration reduction materials could be absorb vibration transferred from the machine to the floor as 97.79 % and after using the rubber belt plate and the rubber valve plate could be increase absorb vibration transferred from the machine to the floor as 98.13 %, 98.71 % respectively.

2. Before using the vibration reduction materials the floor receives the vibration from the machine was at 2.21 percent. After using of the rubber belt plate and the rubber valve plate the floor receives the vibration from the machine was 1.87 percent and 1.28 percent respectively.

6.1.4 Vibration reduction

Findings from comparing percentage in vibration reduction before and after using the different types of the vibration reducing materials indicated the results:

1. The rubber belt plate could reduce vibration at machine all point that could reduce vibration 10.62 percent.

2. The rubber valve plate could reduce vibration at machine all point that could reduce vibration 16.25 percent.

3. The rubber belt plate could reduce vibration at floor all point that could reduce vibration 24.45 percent.

4. The rubber valve plate could reduce vibration at floor all point that could reduce vibration 51.18 percent.

5. The rubber valve plate could reduce vibration more than using the rubber belt plate.

6.2 Recommendations

6.2.1 Recommendations from this study are as follows:

The proper elasticity and properties of the materials could reduce vibration at floor. The suitable material used in this study is the rubber valve plate. Therefore, materials with proper properties should be place at the machine base for reducing danger of vibration to the worker.

If the normal frequency of the materials placed at the machine base to reduce vibration had been known the materials with natural frequency less than 8 Hz. Should be selected because it is effective for reducing vibration when using the machine with velocity 855 rpm or frequency of 14.25 Hz.

6.2.2 Recommendations for further studies

For further studies, the researcher should study the following recommendations:

6.2.2.1 Studying vibration reduction in the different materials by separating frequency to observe intensity of vibration in each frequency interval and ability to reduce vibration of the different materials in each frequency.

6.2.2.2 Studying thickness and ability in vibration reduction from the different materials.

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APPENDIX

APPENDIX A
THEPERSONAL HUMAN VIBRATION METER

Figure A-1 The Personal Human Vibration Meter

APPENDIX B
FIGURE OF MATERIAL IN THIS STUDY

Figure B-1 The rubber belt plate

Figure B-2 The rubber valve plate

APPENDIX C
VIBRATION EXPERIMENTAL RESULTS

Table C-1 Vibration at machine before the use of vibration reduction materials

Point	Measured Vibration (m/s^2)		
	X Axis	Y Axis	Z Axis
1	0.6460	0.4640	3.4300
	1.0300	0.7750	4.8700
	0.8520	0.7220	3.6890
	0.6850	0.5900	2.5310
	0.9260	0.6977	3.5900
mean	0.8278	0.6497	3.6220
2	0.2270	0.1950	2.2342
	0.2714	0.2020	0.5770
	0.3660	0.2810	1.0700
	0.2800	0.2345	1.0050
	0.6950	0.4360	1.1583
mean	0.3679	0.2697	1.0289
3	0.8949	0.6450	1.3820
	1.0012	0.7110	3.9560
	0.6775	0.4240	3.3250
	0.2810	0.2565	0.5835
	0.2780	0.2390	0.5920
mean	0.6265	0.4551	1.9677
4	0.2280	0.1990	1.0950
	0.2977	0.2156	0.6330
	0.8570	0.6895	3.2200
	1.0100	0.7560	4.1660
	0.6685	0.4790	3.3540
mean	0.6122	0.4678	2.4936
Total	**12.1722**	**9.2118**	**46.461**
mean	**0.6086**	**0.4606**	**2.3230**

Table C-2 Vibration at machine when using rubber belt as vibration reduction material

Point	Measured Vibration (m/s^2)		
	X Axis	Y Axis	Z Axis
1	0.6100	0.6230	2.5560
	0.9450	0.5620	3.2415
	0.8280	0.6285	4.5520
	0.6505	0.4980	3.3350
	0.8320	0.6210	2.9841
mean	0.7731	0.5865	3.3337
2	0.5850	0.2116	1.5755
	0.3015	0.2575	0.5985
	0.3548	0.3330	0.6505
	0.2250	0.2241	1.0855
	0.2363	0.2685	1.5365
mean	0.3405	0.2589	1.0893
3	0.6742	0.5575	2.6820
	0.8780	0.4827	1.0485
	0.2560	0.4213	1.5980
	0.2965	0.4550	0.5810
	0.7568	0.2568	2.5010
mean	0.5723	0.4346	1.6821
4	0.5245	0.2750	2.8825
	1.0010	0.4634	1.1370
	0.5232	0.7027	3.4540
	0.2556	0.2366	2.3775
	0.2890	0.4105	1.1523
mean	0.5186	0.4176	2.2006
Total	11.0229	8.4887	41.5289
mean	**0.5511**	**0.4244**	**2.0764**

Table C-3 Vibration at machine when using rubber valve as vibration reduction material

Point	**Measured Vibration (m/s^2)**		
	X Axis	**Y Axis**	**Z Axis**
1	0.6050	0.4685	3.0560
	0.8285	0.5827	2.9787
	0.7356	0.4640	3.8120
	0.6150	0.5850	3.2320
	0.7200	0.6982	2.6841
mean	0.7008	0.5597	3.1525
2	0.2155	0.2185	0.5458
	0.3710	0.2880	1.5930
	0.2360	0.3189	0.5505
	0.2765	0.2285	1.0855
	0.6650	0.2365	1.5365
mean	0.3528	0.2581	1.0622
3	0.9235	0.5360	2.6825
	0.6954	0.3850	1.1320
	0.7262	0.4516	2.1580
	0.2580	0.4640	1.2565
	0.2955	0.2601	1.1523
mean	0.5797	0.4193	1.6762
4	0.9120	0.4815	2.4820
	0.2977	0.3934	1.0285
	0.6310	0.3325	0.5680
	0.2280	0.5513	2.7803
	0.7685	0.4415	2.5980
mean	0.5674	0.4404	1.8913
Total	11.0039	8.3857	38.9122
mean	**0.5502**	**0.4193**	**1.9456**

Table C-4 Vibration at floor before the use of vibration reduction materials

Point	Measured Vibration (m/s^2)		
	X Axis	Y Axis	Z Axis
1	0.0298	0.0272	0.0516
	0.0272	0.0270	0.0528
	0.0270	0.0269	0.0513
	0.0303	0.0290	0.0509
	0.0298	0.0270	0.0521
mean	0.0288	0.0274	0.0517
2	0.0270	0.0271	0.0515
	0.0271	0.0270	0.0513
	0.0270	0.0268	0.0518
	0.0275	0.0271	0.0523
	0.0271	0.0268	0.0509
mean	0.0271	0.0270	0.0515
3	0.0269	0.0268	0.0522
	0.0270	0.0266	0.0515
	0.0270	0.0268	0.0509
	0.0282	0.0269	0.0515
	0.0271	0.0268	0.0517
mean	0.0272	0.0268	0.0515
4	0.0286	0.0271	0.0510
	0.0280	0.0269	0.0514
	0.0285	0.0269	0.0509
	0.0285	0.0268	0.0514
	0.0278	0.0270	0.0509
mean	0.0283	0.0269	0.0511

Table C-4 Vibration at floor before the use of vibration reduction materials (continued)

Point	Measured Vibration (m/s^2)		
	X Axis	**Y Axis**	**Z Axis**
5	0.0273	0.0269	0.0514
	0.0275	0.0269	0.0514
	0.0288	0.0272	0.051
	0.0274	0.0269	0.0514
	0.0269	0.0268	0.0509
mean	0.0275	0.0269	0.0512
6	0.0282	0.0273	0.0511
	0.0306	0.0272	0.0511
	0.0276	0.0272	0.0508
	0.0279	0.0269	0.0506
	0.0273	0.0269	0.0509
mean	0.0283	0.0271	0.0509
Total	**0.8369**	**0.8107**	**1.5405**
mean	**0.0280**	**0.0270**	**0.0513**

Table C-5 Vibration at floor when using the rubber belt as vibration reduction material

Point	Measured Vibration (m/s^2)		
	X Axis	Y Axis	Z Axis
1	0.0264	0.0260	0.0441
	0.0268	0.0258	0.0440
	0.0263	0.0259	0.0340
	0.0264	0.0258	0.0359
	0.0270	0.0255	0.0359
mean	0.0266	0.0258	0.0388
2	0.0255	0.0260	0.0398
	0.0259	0.0258	0.0398
	0.0258	0.0259	0.0384
	0.0261	0.0242	0.0399
	0.0258	0.0260	0.0365
mean	0.0258	0.0256	0.0389
3	0.0260	0.0251	0.0399
	0.0259	0.0256	0.0380
	0.0255	0.0259	0.0385
	0.0261	0.0259	0.0388
	0.0261	0.0250	0.0383
mean	0.0259	0.0255	0.0387
4	0.0263	0.0254	0.0398
	0.0263	0.0251	0.0406
	0.0263	0.0260	0.0383
	0.0261	0.0251	0.0383
	0.0263	0.0256	0.0384
mean	0.0262	0.0254	0.0391

Table C-5 Vibration at floor when using the rubber belt as vibration reduction material (continued)

Point	Measured Vibration (m/s^2)		
	X Axis	**Y Axis**	**Z Axis**
5	0.0263	0.0244	0.0426
	0.0258	0.0244	0.0377
	0.0256	0.0258	0.0365
	0.0253	0.0263	0.0383
	0.0261	0.0260	0.0388
mean	0.0258	0.0254	0.0388
6	0.0265	0.0256	0.0384
	0.0263	0.0273	0.0384
	0.0260	0.0255	0.0385
	0.0261	0.0248	0.0392
	0.0261	0.0249	0.0383
mean	0.0262	0.0256	0.0385
Total	**0.7830**	**0.7666**	**1.1639**
mean	**0.0261**	**0.0256**	**0.0388**

Table C-6 Vibration at floor when using rubber valve as vibration reduction material

Point	Measured Vibration (m/s^2)		
	X Axis	Y Axis	Z Axis
1	0.0239	0.0242	0.0270
	0.0243	0.0239	0.0249
	0.0240	0.0239	0.0272
	0.0253	0.0257	0.0244
	0.0291	0.0239	0.0242
mean	0.0253	0.0243	0.0255
2	0.0242	0.0238	0.0272
	0.0240	0.0238	0.0244
	0.0239	0.0238	0.0265
	0.0239	0.0238	0.0244
	0.0240	0.0239	0.0243
mean	0.0240	0.0238	0.0253
3	0.0239	0.0238	0.0244
	0.0239	0.0238	0.0241
	0.0242	0.0239	0.0244
	0.0240	0.0239	0.0271
	0.0240	0.0238	0.0243
mean	0.0240	0.0238	0.0250
4	0.0251	0.0236	0.0248
	0.0277	0.0238	0.0259
	0.0238	0.0239	0.0245
	0.0238	0.0236	0.0244
	0.0241	0.0238	0.0252
mean	0.0249	0.0237	0.0250

Table C-6 Vibration at floor when using rubber valve as vibration reduction material (continued)

Point	Measured Vibration (m/s^2)		
	X Axis	**Y Axis**	**Z Axis**
5	0.0239	0.0235	0.0244
	0.0239	0.0238	0.0244
	0.0238	0.0243	0.0239
	0.0251	0.0244	0.0238
	0.0251	0.0239	0.0269
mean	0.0247	0.0240	0.0247
6	0.0256	0.0240	0.0243
	0.0254	0.0239	0.0250
	0.0249	0.0238	0.0244
	0.0238	0.0238	0.0270
	0.0238	0.0239	0.0243
mean	0.0247	0.0240	0.0250
Total	**0.7364**	**0.3599**	**0.7520**
mean	**0.0245**	**0.0240**	**0.0250**

APPENDIX D
CERTIFICATE OF CALIBRATION AND CONFORMANCE

No. 9151

DEPARTMENT OF SCIENCE SERVICE

MINISTRY OF SCIENCE AND TECHNOLOGY

CERTIFICATE OF CALIBRATION

FOR : VIBRATION METER (LAB NO.L51/00697.1)

MODEL : HAVPro

SERIAL NO. : 03067

MAKER : QUEST TECHNOLOGIES

TO

DEPARTMENT OF OCCUPATIONAL HEALTH AND SAFETY,
FACULTY OF PUBLIC HEALTH, MAHIDOL UNIVERSITY

DATE OF CALIBRATION : JANUARY 29, 2008.EXPIRED DATE: -

REPORT OF CALIBRATION WITH OUR REF.NO. 0307/2893, FEBRUARY 20, 2008.

(MR. SUN JHITKRAIKROUN)
SCIENTIST 8
ACTING DIRECTOR, PHYSICS AND ENGINEERING PROGRAM

BIOGRAPHY

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