STUDY ON VIBRATION LEVEL OF AGRICULTURE MACHINERY

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STUDY ON VIBRATION LEVEL OF AGRICULTURE MACHINERY

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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Date 11/07/2021……………………….

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/references are appended.

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ABSTRAK

Pemandu traktor terdedah kepada getaran seluruh badan (WBV) yang berpanjangan yang boleh menyebabkan keletihan, sakit kepala, kehilangan keseimbangan dan menggeletar selepas atau semasa pendedahan dan, dalam kes-kes yang melampau seperti gangguan muskuloskeletal yang berkaitan dengan kerja (WMSDs). Sakit belakang adalah salah satu gangguan muskuloskeletal yang berkaitan dengan kerja biasa (WMSDs). Getaran seluruh badan biasanya berlaku apabila pekerja memandu traktor ke atas permukaan kasar dan tidak rata sebagai sebahagian daripada tugas mereka. Getaran seluruh badan disebarkan dari tempat duduk, pemegang dan lantai traktor melalui badan pekerja. Oleh itu, satu eksperimen telah dijalankan untuk meneliti sumber getaran pada traktor. Dalam eksperimen ini, kita akan melihat pelbagai getaran yang dihasilkan oleh traktor serta faktor lain. Getaran yang dihasilkan apabila traktor bergerak pada kelajuan yang berbeza, keadaan trek, seperti padang dan keadaan di jalan raya, dan jarak titik yang diukur relatif ke tanah adalah semua faktor yang akan dinilai. Pada mulanya, untuk mengukur getaran pada traktor, lima accelerometers digunakan di lima lokasi yang berbeza. Accelerometers disambungkan ke LMS Scadas Mobile dan komputer riba. Perisian LMS TestXpress13 digunakan untuk menilai kesan tiga faktor untuk menjana data dan graf. Daripada hasil kajian, kita dapat memerhatikan paras getaran di luar jalan adalah lebih tinggi berbanding dengan jalan raya apabila kita mengukurnya di lantai traktor. Tiada perbezaan yang ketara dalam frekuensi untuk semua kelajuan. Tetapi kita boleh memerhatikan peningkatan getaran yang diukur, kerana kelajuan traktor meningkat. Di samping itu, magnitud ketumpatan spektrum kuasa di pemegang adalah lebih tinggi berbanding dengan lantai, paha, badan dan kerusi. Kebolehpercayaan lantai ke badan jauh lebih besar daripada magnitud lantai ke paha. Jarak badan relatif ke tanah jauh lebih tinggi berbanding jarak lantai ke tanah.

ABSTRACT

Tractor drivers are exposed to a prolonged whole-body vibration (WBV) that can cause fatigue, headache, loss of balance and "shakiness" shortly after or during exposure and, in extreme cases, disorders such as work-related musculoskeletal disorders (WMSDs). Lower back pain is one of the common work-related musculoskeletal disorders (WMSDs). Whole-body vibration usually occurs when employees drive the tractor over rough and uneven surfaces as part of their job. WBV is transmitted from the seat, handle and floor of the tractor through the bodies of the employees who drive them. Therefore, an experiment was conducted to evaluate the source of the vibration on the tractor. In this experiment, we will look at the various vibrations produced by the tractor as well as other factors. The vibration produced when the tractor moves at different speeds, the condition of the track, such as off-road and on-road conditions, and the distance of the points measured relative to the ground are all factors that will be evaluated. At first, to measure the vibration on the tractor, five accelerometers were used at five different locations. The accelerometers are connected to LMS Scadas Mobile and a laptop. LMS TestXpress13 Software is used to evaluate the effect of the three factors to generate data and graphs. From the result, we can observe the vibrational level at off road condition is higher compares to on road condition when we measured them at tractor floor. The no significance difference in the frequency for all the speeds. But we can observe the measured vibration increases, as the speed of the tractor increases. In addition, the magnitude of power spectral density at handle is higher compares to floor, thigh, body and seat. The transmissibility of the floor to the body is far greater than the magnitude of the floor to the thigh. The distance of the body relative to the ground is much higher compared to distance of floor to the ground.

CHAPTER 1

INTRODUCTION

1.1 Introduction

More than 3.5 billion people worldwide, especially in Asia, Latin America, and parts of Africa, have a staple food in Rice. For several years rice has been developed in Asia [1]. Since rice is the main source of food for most Asian countries, over 80% of the rice in the area is consumed worldwide [2]. The best thing to fill in warm spots is rice. It is developed sightlessly on Malaysia's peninsula. The Malaysian peninsula uses about 300500 hectares to produce rice. For year-long rice development, the temperature system and precipitation in the country are reasonable. In a similar period, most farmers are likely to plant and collect as much rice as they can [3].

One of the most dangerous occupations is agricultural jobs. The fatality rate is six times higher according to employment injury figures compared to all other combined manufacturing activities and the increasing number of leisure-related farm injuries is concerned [4], [5].

Occupational exposure has been identified as one of those most important contributors to the onset of chronic disease which, even if it does not result in premature mortality, can lead to serious impairment [6], [7]. Safety concerns of employees include adequate prevention of injuries (which is a result of improved systems) as well as the well-being and comfort sensitivity of the operator [8], [9]. Farmers may also be subject to multiple risk factors at the same time, for example, physical risks (noises, vibrations), environmental (atmospheric dust and chemicals, smoke, etc.), as well as biological risks (spores, micro-organisms and dust pollen), are present in operating agricultural machinery [10].

In agriculture, vibration exposure both in the body and hand is a risk factor. Vibration below 2 Hz has been pointed out that small and temporary effects, like car conditions, which interfere with the desired work performance, can lead to considerable discomfort while long-term exposure to vibrations of two to 20 Hz can lead to severe illnesses, such as degenerative spinal colon diseases [11]–[13].

1.2 Project Background

Agricultural machinery refers to hand tools, animal drawing tools and powered equipment used in the production of crops for various field operations. To make a machine work, the source of power: human, animal or mechanical power must provide input from the physical work. Human work is marked by a limited output of power. In Asia, Africa and South America, animal power is extremely important. Using agricultural machinery helps to improve the timeliness of farming operations and the efficient application of inputs such as fertilisers, chemical substances, and irrigation water to improve land and labour productivity. Also reduces the use of agricultural machinery on the farm [14].

Lower back pain was essentially linked to large operational errands due to organic systems emerging from WBV presentations and incorrect positions, thus identified with attributes of the working environment, use of similar seats, work pace, track or tyres, time and work [15]. The review of 1155 tractor drivers has been completed in one of six above: the vibration in the working vehicle and also the off-base position in driving workouts have been recognised as having the impact of lower back issues for more than 80 % of people interviewed [16].

Workers in agricultural machinery report problems and drawbacks due to delayed sitting. This could lead to vibration transfer to the manager; the pressure of the body scattered over the administrator's bottom, thighs and back; posture taken while sitting; seat cover material and covers; and recognition of ergonomic characteristics[17]. These downsides are usually associated with low recurrence vibrations that are sent to the whole body. The vibration is based on some components, in particular track type and car speed. The entire body vibration is a well-being risk factor because of the degeneration of the rachis structure and the central dorsal position. Based on the workers' report, several experiments were carried out to evaluate vibrations under various working conditions [18].

The engine of the tractor is the main source of the radiated vibration. It can have an important impact on the entire body vibration of the driver even with the smoothest engine. The work condition itself could have done this. In addition, critical parts of the tractor such as the suspension of the seat, front and back axle and the pressure of the tyre are considered. These parts play an important role in changing vibrational values. An experiment to investigate the effect of the various materials used as the tractor seat was conducted as an illustration.

Furthermore, the most relevant designs to use in the machine are only investigated for the front and rear axle suspension. Moreover, to maintain an excellent maintenance system for farm machines with the appropriate tyre pressure research was done. This will make the driver comfortable in driving the tractor. Besides that, the tractor is also monitored for operating speed. This ensures that the driver is not exposed to high-level vibration excessively while trying to avoid longer operating times. High-level vibration can affect the driver although the task is done in a shorter period.

1.3 Problem Statement

In agriculture, agriculture machinery such as tractors is widely used to help farmers perform their jobs. The processes are smoother than before and impact the efficiency when better technology applied to farm machinery. However, agriculture with machines like the tractor causes the driver to suffer from a high-level vibration. It will be worse if the driver is exposed to a long-term high-level vibration. In this experiment, we are going to study the effects of vibrations and the ways of reducing the effects on drivers. The study examines the most important things such as the effect of whole-body vibration (WBV), impact of road condition, distance point relative to the ground and ways of countering the tractor driver's vibrations while doing farm work.

1.4 Objectives

i. To identify the effect on various operating conditions of the entire body vibration on the tractor driver.

ii. To identify ways to overcome those factors and how the vibration can be reduced.

1.5 Scope of Work

The scope of work regarding this project is to research the whole-body vibration that is caused by the operating of the tractor during farming. To determine which frequency range is harmful to the driver, it is possible to measure and record the frequency emission from the tractor. We also need to be familiar with the use of the operative deflection form and its LMS software, as we must measure the tractor vibration under any circumstances. There will also be a real situation of vibration measurement where the vibrations for the tractor will have to be read outside the laboratory. This is to obtain more accurate information on the tractor's vibration in its daily operational environment. There are some limitations during this FYP due to the Nationwide MCO 3.0 situation. The experiment cannot be completed due to a lack of staff. To overcome this, data from few literature reviews are included to support my research.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Whole-body vibration (WBV) is a mechanical vibration that entails risks to employees' well-being, safety, and especially lower back pain and spinal injuries when communicated throughout the body. WBV is a vibration generally transmitted through a farmer's hip into the body. Exposure to high levels of entire-body vibration can result in back injuries and/or exasperate them. These dangers are most visible when the vibration range is high, the introduction time is long, continuous and standard and the vibration is incorporated in [19]. While the reason for these problems is the seat position caused by the bleached seat, the farmer drives up to 12 hours a day and the level of vibration increases their overexposure to high vibrational frequencies [20].

The word introduction of WBV is linked with increased risk to lower back agony, sciatic torment and degenerative spinal cord changes, including lumbar intervertebral plaque disorders [21]. The sizes of the vibration, movement within the body, body posture and the recurrence of the vibration depending on which part of the body is on the way to damage the entire vibration of the body. The human body also does not react in the same way to all frequencies. Figure 2.1 shows the main frequencies of resonance on the body, with different parts of the body having their frequencies.

Table 2.1 Natural Frequency of the main human body [22].

Body part	Natural frequency (Hz)
The whole body	7.5
Body torso	7–13
Head	8–12
Thoracic cavity	4–6
Heart	5
Abdominal cavity	6–9
Spine	10–12
Pelvic	6

The seasonality and periodicity of agricultural productions are generally characterised. For a specific period, drivers must work continuously. Tractors generally operate on field ridge with more excitement on the ground, resulting in a complex and intense vibrations environment in comparison to road vehicles. The domestic tractor vibration rate is mainly between 2.8 Hz and 5 Hz [20].

Also, within the range of vibration ranges which make the operators feel uneasy. The ISO 2631 standards, therefore, suggests that drivers exposed to vibrations of 4 to 8 Hz with adequacy greater than 0.064 g should be able to take a maximum of 8 hours of initial time (root mean square). Full body vibration created by a moving machine such as the tractor often has a spectrum that is below 10 Hz whereas the frequency of resonance of the seated human body is usually only 5 Hz. This resonance frequency comparison makes it possible to cause this effect on the lower back of the vibration resonance [23].

2.2 Important Data about the Whole-Body Vibration of the tractor:

2.2.1 Effect of soil condition

One of those ecological views should be considered when evaluating the driver's vibration. The factor is the dryness rate of the soil where the tractor moves. The dry field causes the working vehicle to vibrate less hypothetically while the wet field gives greater vibration. The following table 2.2 shows the test tracks and forward speed used during the measurement of vibration [24].

Table 2.2 Test tracks and forward speeds used during measurement of vibration[24].

Test tracks	Forward speeds /km·h^{-1}
35 m earthen road (rough tracks)	2.6, 3.8, 6.0, 7.7, 10.9
35 m grassland road (rough tracks)	2.6, 3.8, 6.0, 7.7, 10.9
100 m concrete road (smooth tracks)	3.8, 6.0, 7.7, 10.9, 16.0
100 m asphalt road (smooth tracks)	3.8, 6.0, 7.7, 10.9, 16.0

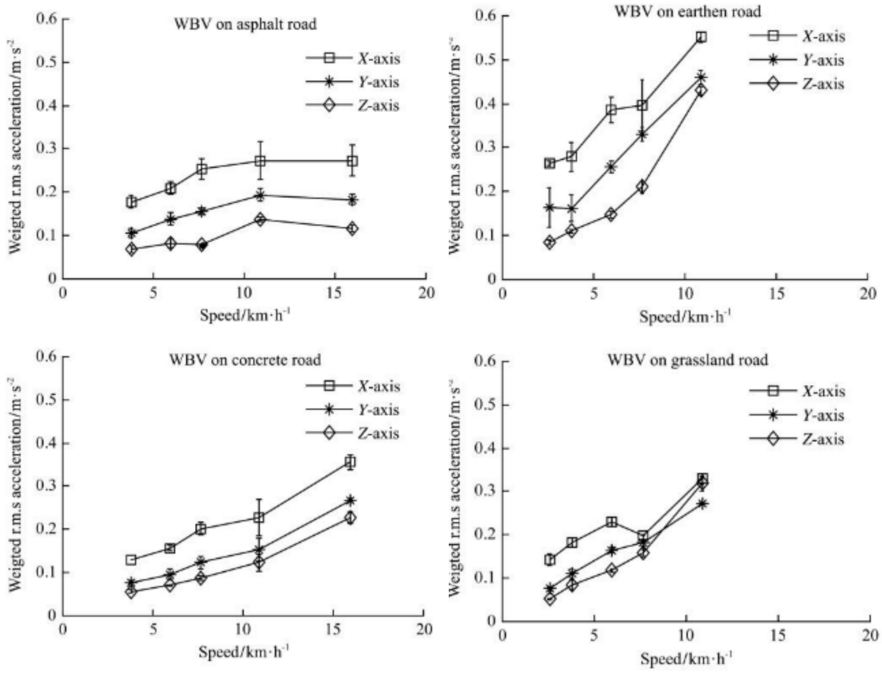


Figure 2.1 WBV measured with various roads with different speeds[25].

Figure 2.1 shows that the type of tracks and forward speeds affected the extrapolated 8-hour daily weighted r.m.s., and normal vibration appreciation increased with speeds such as concrete road and earthen road. The speed of exit was most significantly higher on the grassland roads. Figure 2.2 shows the VDV found at each pivot in terms of rates in each street type. The figure also shows that the types of streets and forward speeds affected the extrapolated VDV values for 8 hours daily [25].

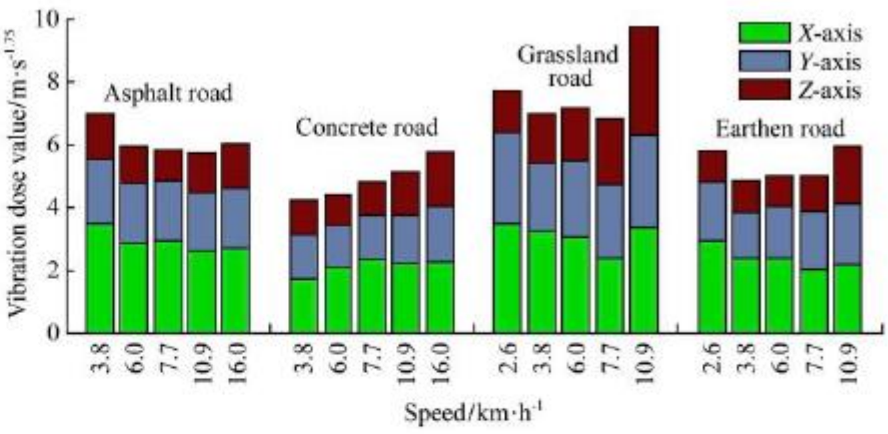


Figure 2.2 VDV found in various roads for different speeds[25].

2.2.2 Effect of type of seat

Seats and pads can constrict the introduction of whole-body vibration (WBV) and reduce the risks of well-being for large machine administrators. During a mechanical suspension seat or a pneumatic suspension seat, various studies demonstrate a reduction in WBV exposure. This can be only true if the suspension system and the seat are configured in an optimum manner. Otherwise, compared with the seat base the vibration measured on the seat can be increased [26].

The conventional seats have a vertical 4 Hz resonance so that at this recurrence and lower recurrent, the vertical vibration is intensified. The seat limits the vertical vibration at or above 6 Hz of recurrence. The spring and the damper system are fitted on suspension seats and have a vertical reverb of around 2-3 Hz. Damper controls reversals and weakens the reversal frequency. It must however be noted that for vertical vibration the most sensitive human recurrence is between 4-8 Hz[27].

Table 2.3 Comparison between different types of seat suspension system characteristics [28].

Seat suspension system	Core damping components	Advantages and disadvantages
Without suspension / rigid seat suspension	cushion	Almost no shock absorption, even amplified vibration.
Linear seat suspension	Linear elastic components	Simple structure, a certain vibration reduction effect; Low cost; Vulnerable to shock and vibration.
Non-linear seat suspension	Non-linear elastic components	Simple structure, high cost performance; Set area vibration reduction effect is good; Prevent shock and vibration; Difficult to adjust, limited function.
Semi-active seat suspension	Semi-active elastic components, controllers	Simple structure, high cost performance; Vibration reduction effect is good.
Active seat suspension	Actuator, feedback controller	Fundamentally attenuates vibration; Complex structure, high cost; Poor stability.

The dynamic suspension of the seat subsequently became the ideal suspension decision [24]. It has an impressive frame for the damping part. The frame is equipped to smoother vibration between 1 Hz and 7 Hz, although the cost of this dynamic seat suspension is costly. The ability to stop the whole-body vibration on the tractor makes it ideally suitable.

2.2.3 Effect of tire inflation pressure

The tractor's tire pressure also plays an important role in minimising the entire body vibration caused by the tractor handling. The effect of tyre pressure was observed in the previous research. In this study, a field test on different transit surfaces at various tyre pressure values of 90 kPa and 160 KPa is performed at the same forward speed of 2.78 ms^{-1}. Table 2.4 shows the tractor mass distribution and configuration used in the field test.

Table 2.4 Tractor mass distribution and configuration[29].

Test group	Tire pressure	Speed	Front mass		Rear mass		Total
	kPa	ms^{-1}	kg	%	kg	%	kg
1	90	2.78	1530$^{(1)}$	40	2220$^{(1)}$	60	3770
	160	2.78	1530$^{(1)}$	40	2220$^{(1)}$	60	3770

The crossed surface was the parameter affecting both the seat and platform vibration total values in field tests of 2.78 ms^{-1}, as well as tyre pressure of 90 kPa and 160 kPa. In the high-pressure level of the mean total vibration value as shown in Figure

2.3, tyre pressure indicates a growing trend. The vibration total values a_v were higher at a pressure of 160 kPa both on the platform and on the seat. Due to the exception of the acceleration measured in the tyre pressure of 160 kPa on the platform, the asphalt a_v is always less than 0.5 ms^{-2}. In the harrowed clay and grass at 160 kPa, the maximum total vibration is more than 1.21 ms^{-2}, while at passages of farm area the values were approx. 1 ms^{-2} [29].

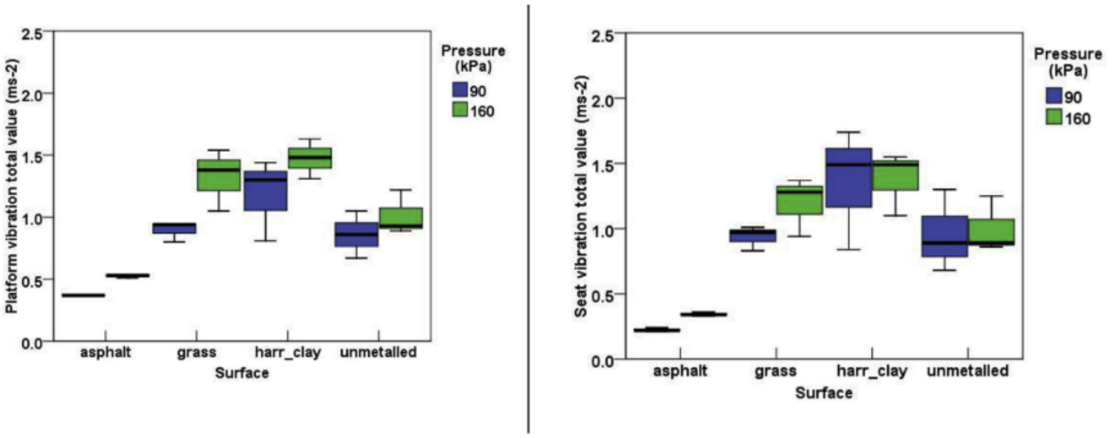


Figure 2.3 Graph of the vibration total values measured on the platform and on the seat with the tractor crossing all the surfaces at the tire pressure of 90 kPa and 160 kPa [29].

2.2.4 Low Back Disorder

Several epidemiological studies have shown the increased risk of musculoskeletal disorders in the back of tractors. The vertebral column and its supporting structures during the tractor movement are overloaded by different environmental factors. The most significant stressors contributing to the development and onset of musculoskeletal problems among professional drivers are excessive exposure to whole-body vibration (WBV).

Table 2.5 shows the age-adjusted odds ratios for LBP according to various work- and individual-related factors. The most important predictors for lifespan, transient, or chronic LBP in the sample are age, occupation, vibration exposure, perceived postural load and back trauma. Transient LBP was also linked to sports and education. In general, LBP tended to increase as car driving increased, but the association was not substantial.

Table 2.5 Age-adjusted odds ratios (OR) and 95% confidence intervals (95% CI) for lifetime, transient and chronic low-back pain (LBP) according to various work- and individual-related factors[16].

	Lifetime LBP		Transient LBP		Chronic LBP	
Factor	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Age (years)*						
<30	1.0	–	1.0	–	1.0	–
31–40	2.29	(1.62–3.23)	1.59	(1.14–2.22)	1.73	(1.18–2.55)
41–50	4.37	(3.02–6.33)	2.51	(1.80–3.50)	2.17	(1.49–3.16)
>50	6.44	(4.52–9.17)	3.42	(2.50–4.67)	3.24	(2.29–4.59)
Occupation						
Controls	1.0	–	1.0	–	1.0	–
Tractor drivers	4.05	(2.92–5.61)	2.88	(2.09–3.96)	2.12	(1.44–3.16)
Total vibration dose (years m^2/s^4)						
0	1.0	–	1.0	–	1.0	–
<15	3.28	(2.26–4.75)	2.45	(1.71–3.50)	1.69	(1.10–2.59)
15–30	4.43	(2.97–6.61)	3.29	(2.27–4.77)	2.34	(1.52–3.58)
>30	5.49	(3.57–8.45)	3.25	(2.21–4.77)	2.63	(1.70–4.05)
Postural load (grades)						
1 (mild)	1.0	–	1.0	–	1.0	–
2 (moderate)	1.97	(1.17–3.32)	2.25	(1.33–3.83)	1.54	(0.80–2.95)
3 (hard)	3.20	(1.97–5.19)	2.95	(1.79–4.84)	2.19	(1.19–4.03)
4 (very hard)	7.51	(4.57–12.3)	6.27	(3.82–10.3)	3.27	(1.80–5.96)
Back trauma						
No	1.0	–	1.0	–	1.0	–
Yes	3.62	(2.18–6.03)	2.16	(1.52–3.06)	2.19	(1.62–2.94)
Education (years)						
>8	1.0	–	1.0	–	1.0	–
8–5	1.44	(1.04–1.99)	1.39	(1.03–1.88)	1.32	(0.95–1.84)
<5	1.37	(0.93–2.04)	1.44	(1.02–2.02)	1.35	(0.95–1.92)
Body mass index (kg/m^2)						
<24	1.0	–	1.0	–	1.0	–
24–27	1.05	(0.77–1.42)	0.95	(0.73–1.25)	1.15	(0.86–1.53)
>27	1.17	(0.82–1.66)	1.29	(0.95–1.74)	1.27	(0.94–1.72)
Sport activity						
Yes	1.0	–	1.0	–	1.0	–
No	1.36	(0.99–1.88)	1.53	(1.14–2.07)	1.35	(0.97–1.89)
Car driving (km per year)						
<5000	1.0	–	1.0	–	1.0	–
5000–15000	1.23	(0.79–1.92)	1.01	(0.67–1.48)	1.06	(0.71–1.57)
>15000	1.47	(0.99–2.18)	1.20	(0.85–1.70)	1.38	(0.98–1.93)
Smoking habit						
No	1.0	–	1.0	–	1.0	–
Yes	0.95	(0.72–1.26)	0.93	(0.72–1.19)	1.0	(0.75–1.31)
Marital status						
Non-married	1.0	–	1.0	–	1.0	–
Married	1.35	(1.01–1.81)	1.29	(0.99–1.68)	1.0	(0.77–1.29)
Previous jobs at risk						
No risk	1.0	–	1.0	–	1.0	–
Heavy physical work	0.96	(0.67–1.46)	1.09	(0.75–1.59)	1.29	(0.90–1.88)
Vibration exposure	1.06	(0.49–2.28)	1.23	(0.64–2.35)	1.07	(0.58–1.97)

*Crude OR

The trend statistics have shown that the occurrence of the lowest back symptoms in the sample as a continuous logarithmic variable has been increasing with the increasing dose of vibration. Only the lifetime prevalence of LBP showed a positive trend with vibration exposure when the analysis was carried out in the tractor driver's group. The pattern of changes of logistic regression ratios, however, showed a less related equivalent vibration magnitude to low-back disorders than the duration of WBV exposure [16].

2.2.5 Exposure limit of WBV

Recently, a 0.5 ms^{-2} (e.g., 8 h energy-equivalent frequency-weighted acceleration) action level for whole-bodies vibration has been proposed in the annexe to a proposed Directive on physical agents prepared by the Commission of the European Communities which provides information on the exposed workmen, technical measures and health surveillance. Although the uncertainty related to the estimate of the daily exposure time is considered, the exposure data of this study suggest that the whole-body exposure for tractors is higher than that indicated above. Compared with the controls, the increased risk of chronic LBP among tractor drivers seems to be consistent with the hypothesis that the driver group will experience excessive exposure to WBV, with a long-term effect on the lower back [16].

Therefore, to prevent adverse health effects resulting from a lengthy WBV exposure, the exposure limit suggested by the European proposal appears more appropriate than that of the ISO standard. The proposed limits could be based on short-term laboratory specimens experiments, rather than epidemiological studies by people with prolonged vibration exposure, as one cause of the failure of ISO 2631-1 to prevent health impairment [30]. At least partially the time dependence in the ISO standard may also result from the observed discrepancy, in that large vibration rates are permitted for short exposure durations.

CHAPTER 3

METHODOLOGY

3.1 Overview

In this chapter, the details of the experiment procedure along with the equipment and material is presented. Firstly, the tractor specification is used to measure the vibrational level. Besides, LMS Scadas Mobile are needed to be set up before the experiment being conducted. Next, is the fabrication of the LMS Scadas Mobile base. As there no stable position on the tractor that can be used to put the LMS Scadas Mobile, a fabrication was done. The steps include designing, preparation of material and fabrication of the product. Lastly, we will set up the tractor for the measurement. A few positions will be selected to put the accelerometer to measure the vibrational level.

3.2 Tractor specification

For measuring the vibration at certain points on the tractor, a Massey Ferguson MF4708 tractor is chosen. Table 3.1 below shows the specifications for the tractor. Measuring is performed at the Universiti Sains Malaysia (USM) Sports Centre's Nibong Tebal Engineering Campus.

Table 3.1 General Specification of Massey Ferguson MF4708 Tractor.

Engine	Bore/Stroke(mm)	108x120
	Power (hp)	80
	Maximum Power(hp)	85
	Rated RPM	2200
Dimension	Wheelbase(cm)	224
	Rear axle	Flange
Transmission	Type	power shuttle

	Gears	12 forward and reverse
	Clutch	Wet disc

Figure 3.1 Massey Ferguson MF4708 Tractor[31].

3.3 The Setup of the LMS Scadas Mobile

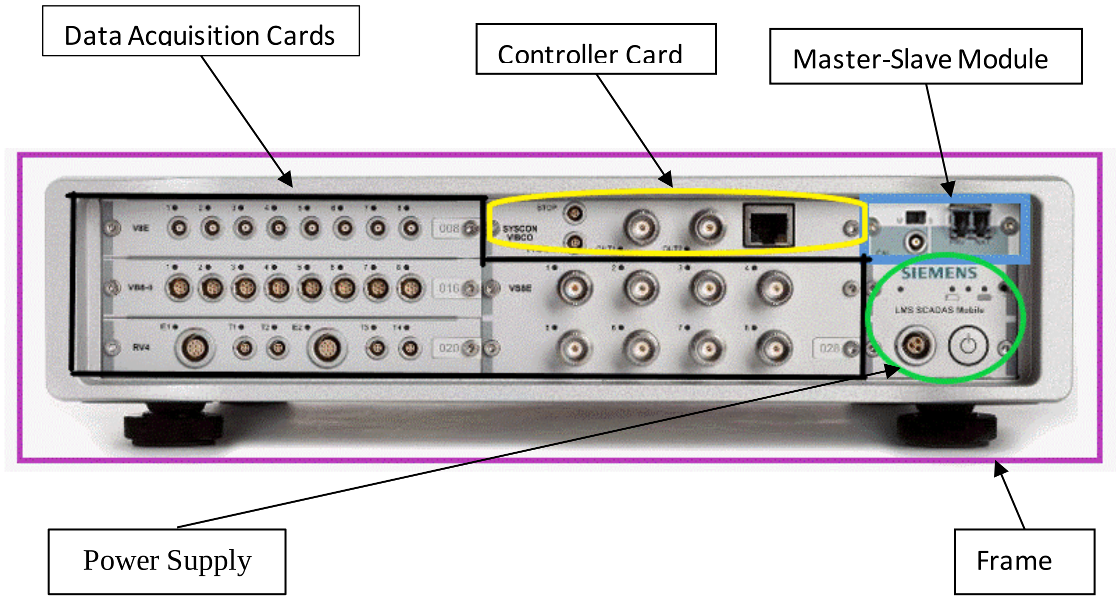


Figure 3.2 The LMS Scadas Mobile[32].

The LMS Scadas Mobile used during the measurement process is from Siemens PLM Software. It is mainly designed for high shock, vibration, and temperature ranges. In addition, it is the ideal measuring system on the move. Furthermore, it is a suitable device to be used for the assessment of vibrations while moving either on the testing ground or under rough measurement conditions for a period. In addition, the system can be connected directly to a PC for the visualisation, processing, and storage of signals via autonomous recording.

3.4 The Fabrication of LMS Scadas Base

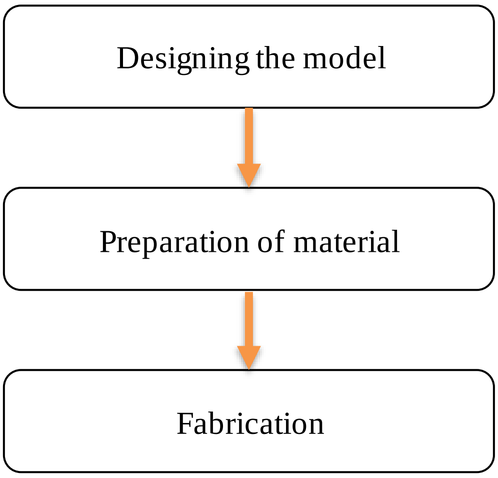


Figure 3.3 Process of Fabrication of LMS Scadas Base.

Figure 3.3 shows the process needed to fabricate the base for LMS Scadas Mobile. Firstly, the model will be created by using Solidworks. The model that was created using Solidworks can be seen in Figure 3.4.

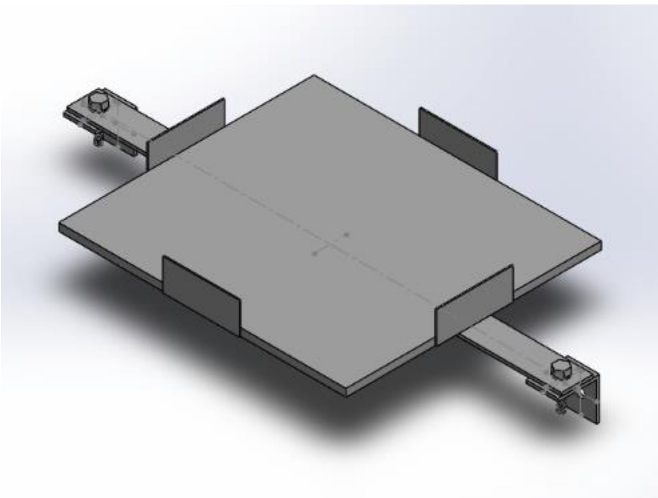


Figure 3.4 Model created using Solidworks.

Secondly, during the preparation of material, we list down all the materials and processes needed to fabricate the product. The materials needed include plywood, hollow aluminium, iron bar, sheets of metal and angle bar. So, the process includes sawing using a hand saw, cutting using a cutting wheel, and creating holes using parallel drilling. To assembly, all the parts, MIG welding is used to connect the hollow aluminium frame with an iron bar. For plywood and hollow aluminium frame, riveting is used. 4 sheets of metal are welding to the edge of the frame to prevent the LMS Scadas Mobile from falling during the experiment. Figure 3.5 shows the top and bottom views of the final product.

Figure 3.5 (a) Top and (b) Bottom views of the final product.

3.5 The Setup for the measurement on the tractor.

Firstly, is the preparation of LMS Scadas Mobile. LMS Scadas Mobile is installed at a firm and static location on the tractor. In this case, the back of the tractor is selected to install the base for LMS Scadas. Figure 3.6 shows the position of the LMS Scadas Mobile.

Figure 3.6 Position for LMS Scadas Mobile.

The accelerometer is used as an input for the LMS Scadas Mobile. It will measure motion or vibration by converting physical movement into an electrical signal. Figure 3.7 displays a general connection for vibration and modal analysis measurement equipment and sensor.

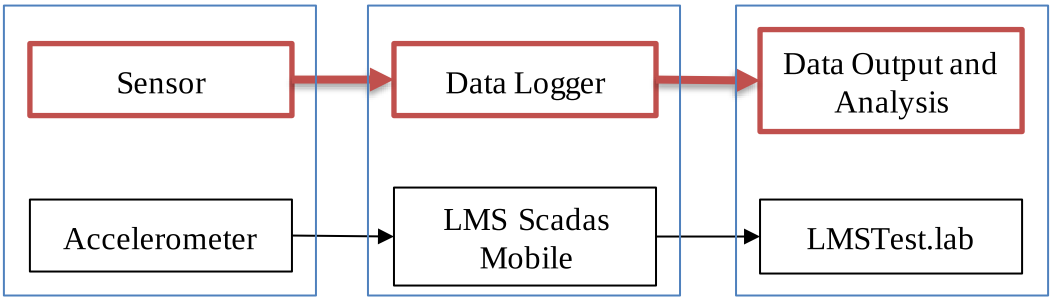


Figure 3.7 General connection for vibration and modal analysis measurement equipment and sensor.

In this experiment, 5 accelerometers are used to connect to LMS Scadas Mobile. The accelerometers are installed at 5 specific locations on the tractor. The location of the installed accelerometers is shown in Table 3.2. As in Table 3.2, we have 5 accelerometer inputs.

Table 3.2 labellings for the accelerometers and their specific positions.

No	Channel	Location of Accelerometer
1	1	Floor

2	3	Thigh
3	4	Body
4	5	Hand
5	6	Seat

As we want to study the effect of the vibration, we place the accelerometer at every important point of the tractor that is attached to the human body while driving. The first is the floor where the driver steps and feet are placed. The second and third points concern the assessment of the vibrations in the thighs, where the driver leans their back. Both points are studied to obtain a comparison of the results between their height and their effect on the vibration at these specific points.

3.6 The use of LMS TestXpress.13 Software

LMS Software used to support this research is shown in Figure 3.5 by Siemens PLM Software. LMS TestXpress13 is the name of this software. This software was also used while measuring the moving tractor. The time-domain diagram was able to be recorded with the frequency domain diagram. This experiment had a time range of 15 seconds for the measurement.

Upon completion of the measurement, data from this software were generated. Two further graphs, the root-mean-square graph and power spectrum density graph were drawn through coding in this software. The figures below show how the other two graphs are drawn.

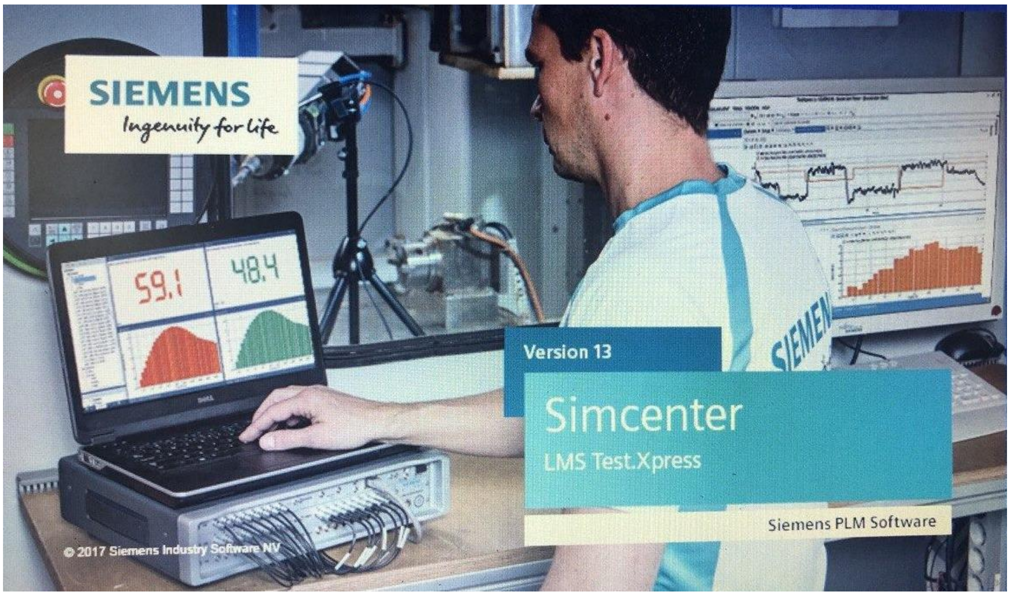


Figure 3.8 LMS TestXpress13 by Siemens PLM Sofware.

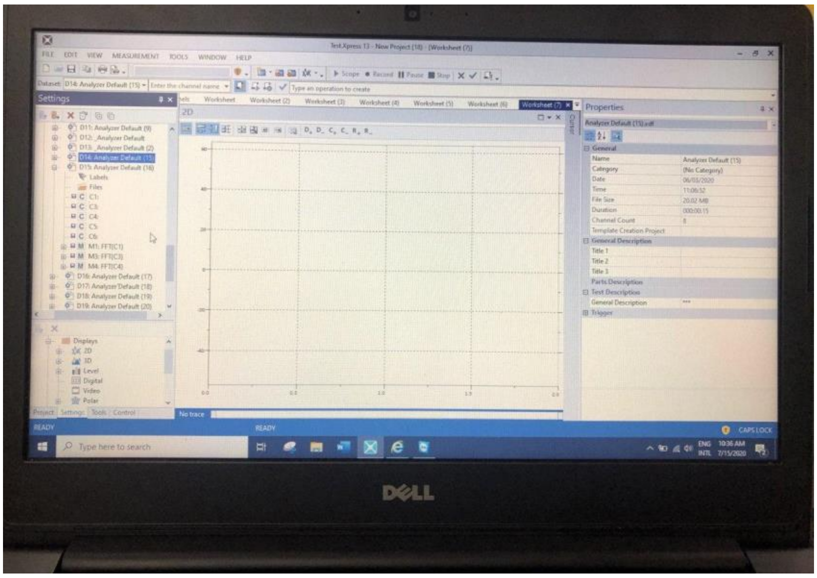


Figure 3.9 Interface of the LMS TestXpress13.

CHAPTER 4

RESULT & DISCUSSION

4.1 Overview

In this chapter, we will discuss the result of the LMS Test. Xpress 13 Software from last year student which Mohd Aminul. There will be two data under LMS Software which are analyzed for various speeds at the same position and analysis for various positions under the same speed. We also discuss the result from the vibrational level measurement from literature reviews such as from S. Aisyah Adam and Nawal A. Abdul Jalil, and Roberto Deboli, Angela Calvo, Christian Preti. From S. Aisyah Adam and Nawal A. Abdul Jalil research, we will the power spectral density, transmissibility and coherencies, and Root-mean square vibration magnitude. For Roberto Deboli, Angela Calvo, Christian Preti research we will observe the result from field tests at different tire pressure, different for forward speeds and with or without ballast and on various transit surfaces with or without instruments.

4.2 The result from LMS Test.Xpress 13 Software.

LMS Test. Xpress 13 Software has been used to generate data for both the Time-Domain Graph and the Fast Fourier Transform (FFT) Graph. The time-domain graph shows the vibration variation for about 15 seconds, while the Fast Fourier Transform (FFT) graph shows the root-mean-square acceleration variation against the frequency.

Figure 4.1 is the Time-Domain graph. It shows the vibration fluctuation in 15 seconds. While in Figure 4.2 is the Fast Fourier Transform (FFT) graph. The graph shows the amplitude variation of the vibrations along with the frequency.

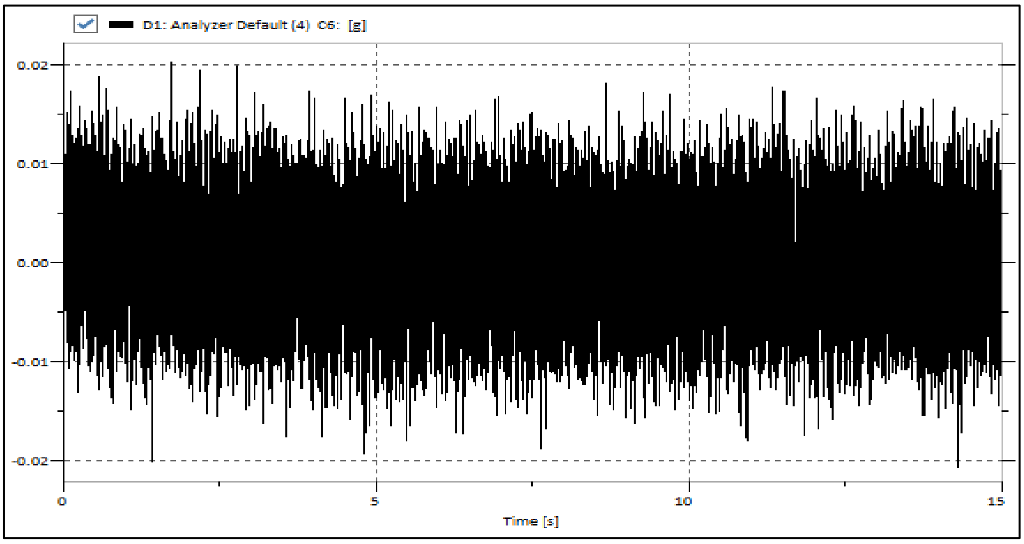


Figure 4.1 Time Domain graph.

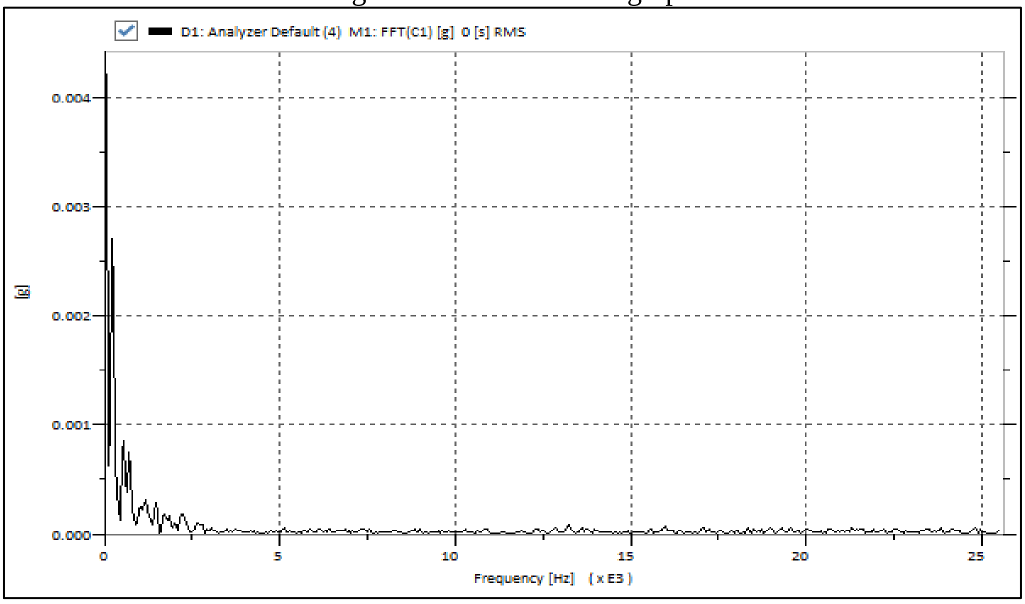


Figure 4.2 Fast Fourier Transform (FFT) graph.

From the previous study, for the most data collected, the FFT graph produced from the software shows the same pattern. The amplitude is high while the tractor just starts moving, and with increasing frequency, the amplitude drops. The amplitude is reduced to a constant, as the tractor speed after 0.75 Hz is constant.

4.2.1 Analysis for Various Speed with the Same Position.

Table 4.1 shows the result generated from vibration level measurement under various positions.

Table 4.1 Data summary for Vibration Level Measurement.

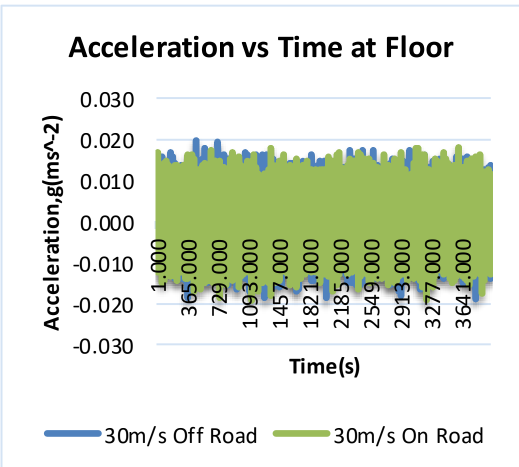
No	Test Methods	Channel Setting	Position of Accelerometer	Speed(m/s)	Conditions
1	i-Operating Deflection Shape ii-LMS Software	1 3 4 5 6	Floor Thigh Body Hand Seat	30 40 50 60	Off Road On Road

The accelerometer is connected to the floor of the tractor. The data are produced with LMS software for 15 seconds. For measuring the levels of vibration of the field (Off-Road) and tarmac (On-Road), two routes are observed. In this test, the most vibratory amplitude parts of the tractor were indicated. The driver can also clearly identify the cause of the entire body vibration (WBV). Table 4.2 shows the results of vibration level measurement for all four speeds available.

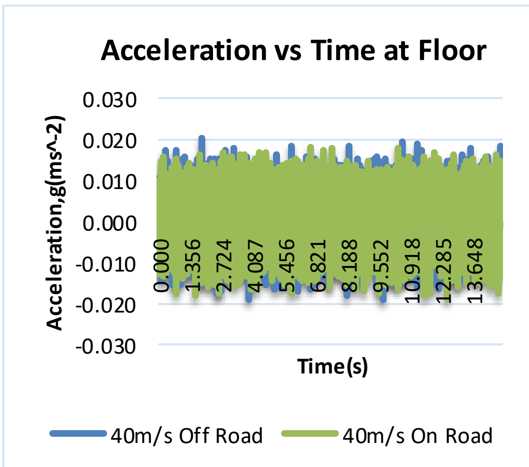
From table 4.2, we can observe the value of vibration displayed in 15 seconds is not exceeding 0.02 ms^{-2}. We also can observe that the vibrational level of off-road is greater compares to on-road conditions. However, the difference between both conditions always fluctuating between each other in the time-domain graph.

Table 4.2 Vibration Level Measurement at floor position by different speeds under two conditions

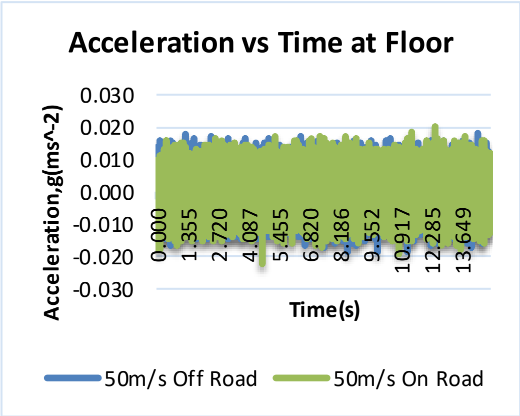
(a) Speed: 30m/s



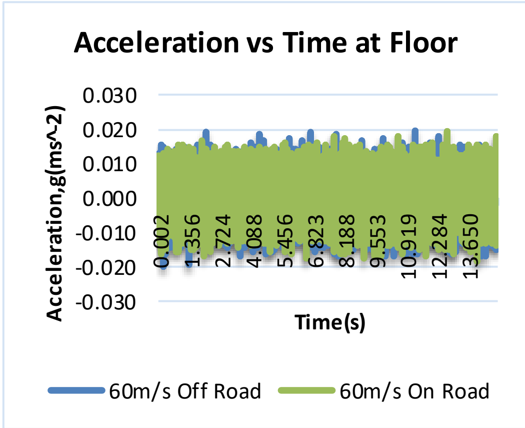
(b) Speed: 40m/s



(c) Speed: 50m/s



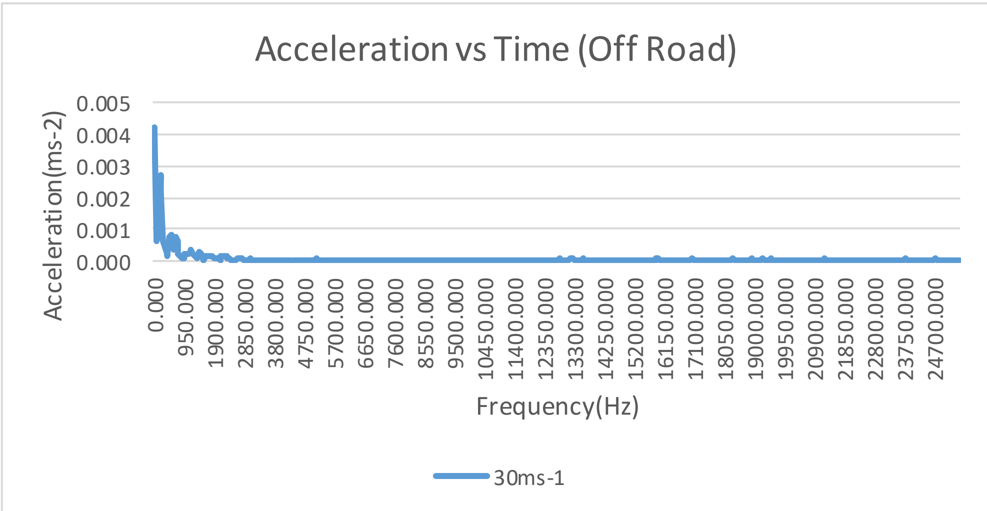
(d) Speed: 60m/s



By comparing its FFT graph, we can effectively observe the significant difference between off-road and on roads for its vibrational level. Table 4.3 illustrates the FFT graph in two ground conditions of the vibrations measured on the ground at the speed $30s^{-1}$.

Table 4.3 FFT Graph of both conditions measured at speed of $30ms^{-1}$.

(a) Field (Off-Road)



(b) Tarmac (On-Road)