Effect of Vibration on Human Body

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1. Introduction

1.1. Background of Studies

Vibration is a movement of an object in oscillatory motion [1]. All of the object that content elasticity a mass elements are capable of vibration. There are many types of experiments have been done to investigate between vibration in the vehicle effects on level of mental alertness in seated driver however it is still insufficient. For the reason is the level of mental alertness and drowsiness caused by vibration is still a complex phenomenon due to several factor such as traffic control and vehicle interior noise [2]. Vibration of the vehicle can cause various effect on the structure within the body such as organ, body tissues, and systems of the individual as the vibration is transmitted from the vehicle seat to a person body.

There are two types of vibration that occurs on the vehicle, free vibration and force vibration [3]. Free vibration occur when the vehicle is passing the non-rough road surface and the vibration may gone as a result of the dispersion of the energy in damping. Then the force vibration is occur when the road is rough and the disturbance continuously occur as the vehicle pass the obstacles.

Human body can tolerate a specific amount of vibration energy. The body will start to decline and causes a long-term effect damage of the whole body process. Through that, International Standard, ISO 2631-1, 1997 have been developed to evaluate of human exposure to whole-body vibration (WBV). Although the International Standard has been developed, there is still little amount of knowledge on how the vibration can affected exhaustion.

1.2. Problem Statement

The notable cause of accidents on motorways is driver fatigue. Research found that around one-quarter of serious vehicle accidents are because of the sleepy drivers. This mean, sleepy driver cause more accidents than drunk driving [2]. Fatigue impact by long-driving hours cause decrease in driver alertness and performance. Long exposure to vibration also can affect the body performance and visual impairment of the driver. However vibration of vehicle on human body is not well analyze in the available literature. This is because complexity of fatigue nature, and there is only small amount of data exists. Therefore, in this project we would like to focus on the effect of vibration on mental alertness of individual hence minimize the vibration energy using simulation.

1.3. Objective

The objective of this project is to simulate vibration body of vehicle using software such as ANSYS. ANSYS is a software on simulating the interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic.

On top of that, the objective of this project is to reduce vibration energy causes by the vehicle. The idea is to minimize the whole-body-vibration (WBV) that transmitted from the seat of the driver.

1.4. Scope of Study

Propose of this project is to simulate the vibration body of a vehicle and compute the technical data receive. It is involving simulation by using software like ANSYS. By using this software, we got to know the general view on how the vibration working and in addition to minimize the vibration energy of the body of the vehicle

2. Literature Review

2.1. Effect vehicle vibration on human body

It is necessary to include human body when dealing with vehicle vibration to study the physical characteristic of it. The effect on body due to the vibrations is mechanical, physiological and also performance of human [5]. Mechanical damage can cause when the accelerative force is in adequate magnitude. Besides that, long-term exposure of vibration can cause chronic injuries to human body. Mechanical damage also results impact injuries to the spinal column, such as fracture of vertebrae. It is observe most of the injuries occurs on the whole-body-vibration (WBV) occupant such as car operator and truck driver.

Physiological effect of vibration is depending on the vibration frequency of the vehicle. The table below show the effects of human body on the frequency of the vibration [6]:

Table 1: Frequency of vibration and its effects on the human body

Frequency of vibration	**Types of effect**
Below 1 Hz	Motion Sickness
3.5 to 6 Hz	Alerting effect
4 to 10 Hz	Chest and Abdomen pain
Around 5 Hz	Degrades manual actions
7 to 20 Hz	Communication Problems
8 to 10 Hz	Back ache
10 to 20 Hz	Intestine and Bladder pain
10 to 30 Hz	Degrades manual and visual controls
10 to 90 Hz	Degrades visual actions

For performance effect, the substantial affects are mainly on visual and motor performance. Most of visual impairment occurs in range of 10 to 25 Hz of vibration frequencies. The key factor of impairment of the visual performance is the amplitude of the vibration due to movement image of the retina. It causes visual blur at frequencies below than 3 Hz. The characteristic of object being viewed have crucial effect on the performance in the vibrating situation. Table below show resonant frequencies of various body structure in sitting position and range of vibration rms acceleration for comfort [3]:

Table 2: Resonant frequencies of various body structure in sitting position

3-4 Hz	Resonance in cervical vertebrae (neck)
4 Hz	Peak resonance in lumbar (upper torsos) vertebrae
5 Hz	Resonance in shoulder girdle
20.3 Hz	Resonance between head and shoulders
60 Hz	Resonance in eyeballs.

Table 3: Range of vibration rms acceleration for comfort

Less than 0.315 m/s^2	Not uncomfortable
0.315 to 0.63 m/s^2	A little uncomfortable
0.5 to 1m/s^2	Fairly uncomfortable
0.8 to 1.6 m/s^2	Uncomfortable
1.25 to 2.5 m/s^2	Very uncomfortable
Greater than 2 m/s^2	Extremely uncomfortable

From the table shown above it is very crucial to avoid any of damage impact to the body. From the resonance table it is must avoid any of the range frequency. It is safe to say the comfort range of resonance is below than 3 Hz. For the RMS acceleration, it is comfortable as long as the range is below 0.315 m/s^2.

2.2 Effect of vibration on the brainwave activities

Brainwave activities are produce by the masses of electrical impulse by neurons communicating with each other. One of the reliable method to measure the brainwave activities by detecting the range of the frequency using electroencephalography (EEG) [7]. EEG work by measuring the potential difference of brainwave activities using a scalp as electrodes and the using measured is in microvolt range. The frequency range and the state of the person at the moment of the frequency are shown in the table:

Table 4: The frequency range and the state of the person at the moment of the frequency

Type of brainwave activity	**Frequency**	**State**
Beta	14-20 Hz	Alertness and wakefulness
Alpha	8-13 Hz	Relaxed condition but conscious
Theta	4-7 Hz	State of drowsiness
Delta	0.5-4 Hz	Deep sleep condition

From the experiment conduct by the RMIT University, Australia [2], it’s shown that the result obtains in low frequency vibration stimulate the drowsiness and declining in alertness. To compare between the random and sinusoidal motion condition, the drowsiness effect is less likely effect on the random motion of vibration. This is shown that in the harmonic motion condition has great influence on occupant drowsiness level. This condition happened because of less sensory stimulation occur on the body of the occupant and less sensory receptor stimulate on human body, hence the occupant will decline in wakefulness level.

Comparing between the type of brainwave activity, in 20 minutes of exposure, reduction occur in beta brainwave activity and increase in theta brainwave activity. Therefore, it is shown that in only 20 minutes of interval during exposure of the vibration motion can cause declining in a state of alertness and increase in a state of drowsiness.

2.3 Effect of vibration on perceptual and cognitive performance

Become aware of something or interpreting ability by using our sensory is the definition of perceptual, besides cognitive performance is understanding through thought, experience, and sense by acquiring knowledge and mental action. Research shows that around 5 Hz of vertical vibration, it is mostly effected the tracking performance and writing [8]. It is suggested that for horizontal vibration, frequencies below than 3 Hz have a negative effect on tracking but still little knowledge available for this effect.

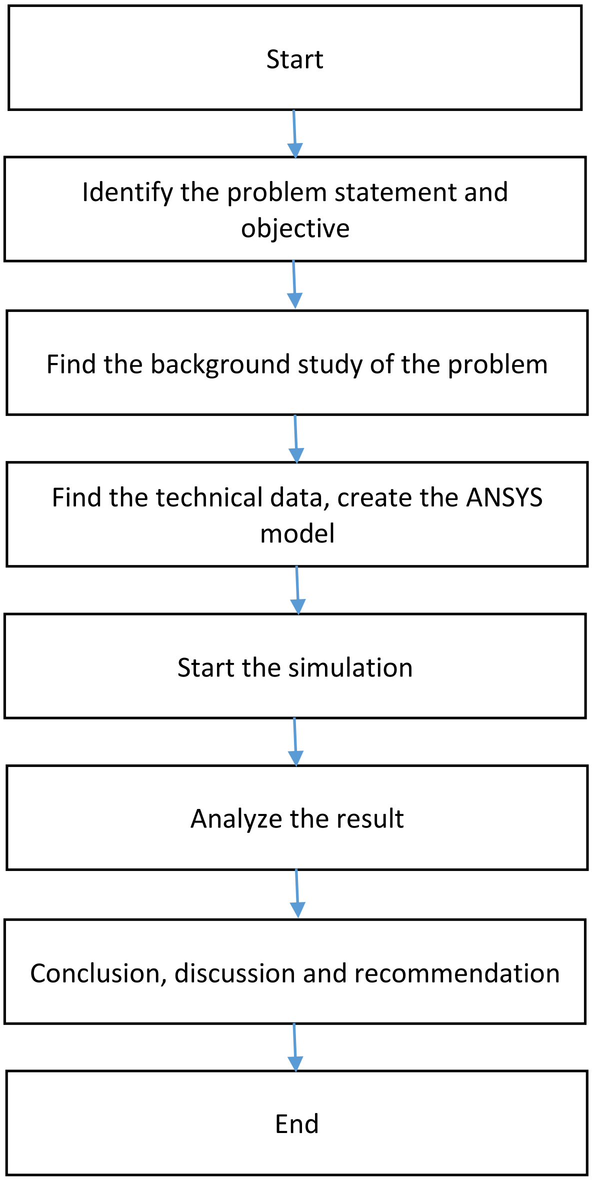
For visual activities, between 2 and 20 Hz range of frequencies is affected and declining the optimal viewing distance such as the image of text font or image size and collimated displays. From the other sides, vibration doesn’t have significant effect on skin temperature and heart rate. In addition, simple reaction time also does not appear to be affected the by the vibration. Ljungberg et al. (2004) combining noise with 16 Hz vibration to study the effect of short-term memory with the vibration. The results are, there is no significant differences between the noise and the vibration amplitude effect on the short term memory [9].

3. Methodology

3.1. Analysis Tools and Project Flow Chart

Methodology use in this project is involving computer software ANSYS. Because vehicle have randomization vibration, it is hard to analyze how the vibration work in vehicle. Therefore, we assume the vibration as sinusoidal (harmonic motion) and two dimensional body for the first try. It is to ensure better understanding on the vibration object.

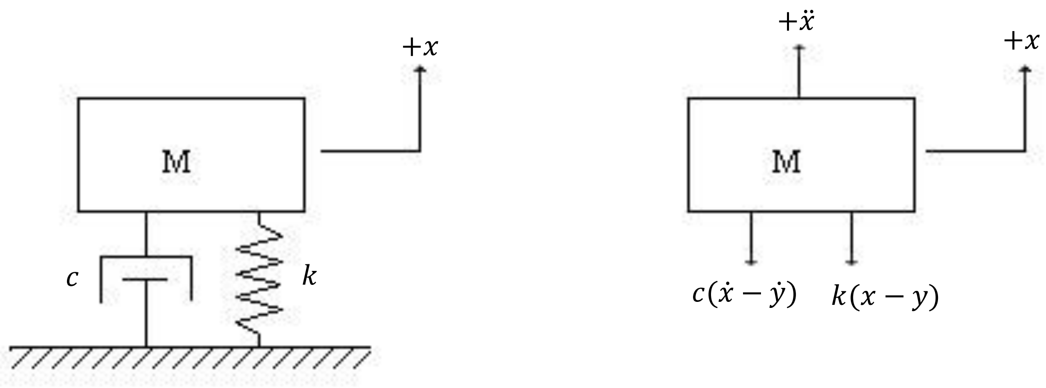
Figure below shows the project flow chart in order to achieve the objective:



3.2 Theory

The simulation is to assume to be undergoes sinusoidal vibration of motion (harmonic motion). For the simulation purpose, it is considering the system undergoes one degree of freedom [10]. Figure below shows the free body diagram of the vibration transmitted from the seat to the vehicle chassis:

Diagram 1: chassis to seat excitation in vibration



Where x = displacement of the mass (seat)
y = displacement of the base (chasis)
$\dot{x}$ = velocity of the mass
$\dot{y}$ = velocity of the base
$\ddot{x}$ = acceleration of the mass

From the equation we can calculate the value of the amplitude of the mass, X and base, Y.

$$\frac{X}{Y} = \left[\frac{1 + (2\zeta r)^2}{(1 - r^2)^2 + (2\zeta r)^2}\right]^{1/2}$$

Where X = Amplitude of the mass
Y = Amplitude of the base
ζ = Damping ratio
r = Frequecy ratio

Amplitude of velocity felt by occupant

$$\omega X = 2\pi f X$$

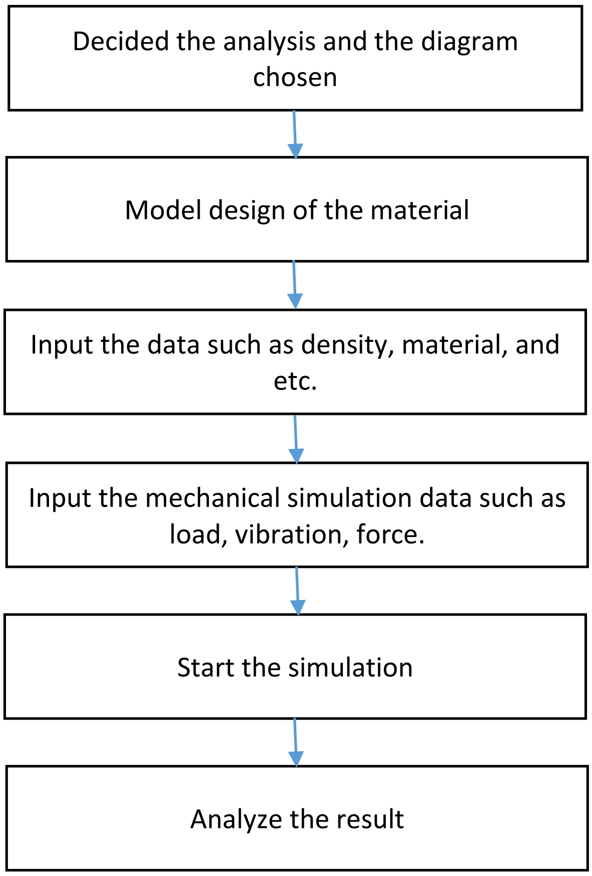
Where ω = frequency of oscillation
f = linear frequency

Acceleration felt by the occupant, $\omega^2 X$.

From the equation given we can refer from the table given in the literature review shows how severe the injury can occur to the occupant base on the data and input from the simulation.

3.3 ANSYS Software

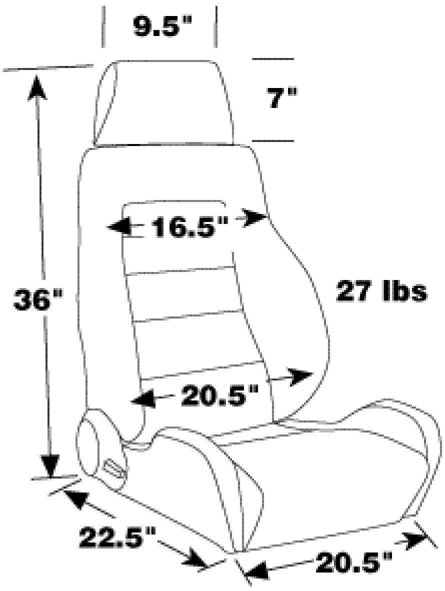
Below is the procedure flow for the software:



3.3.1 Diagram Chosen and Model Design

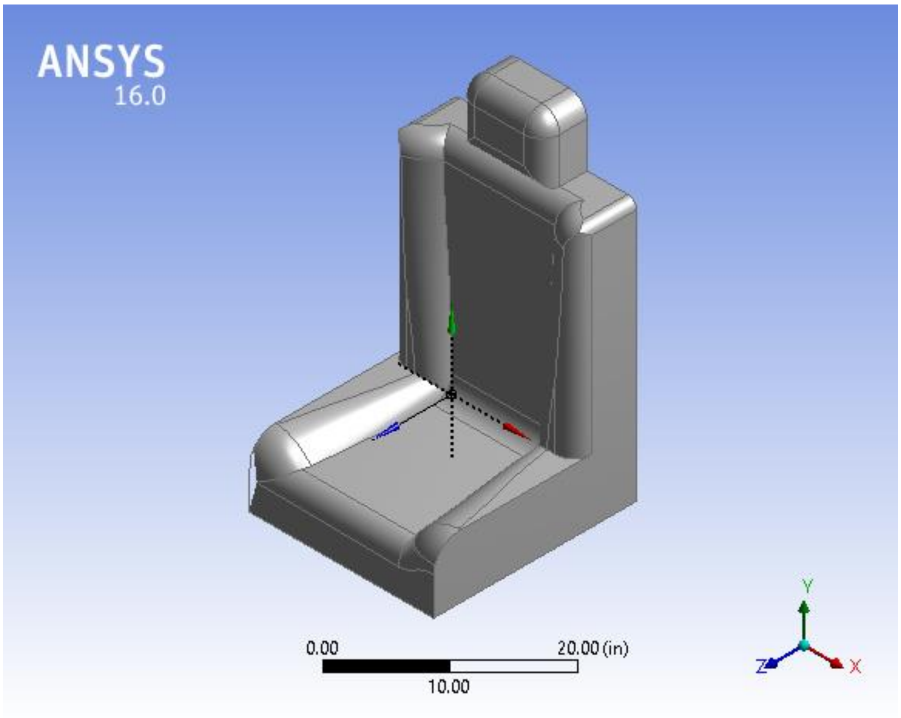
Diagram below shows car seat dimension that have been chosen.

Diagram 2: Dimension of the chosen car seat



The chosen dimension then creates using ANSYS DesignModeler. The following diagram shows the result of the model:

Diagram 3: Result of the geometry from the chosen dimension

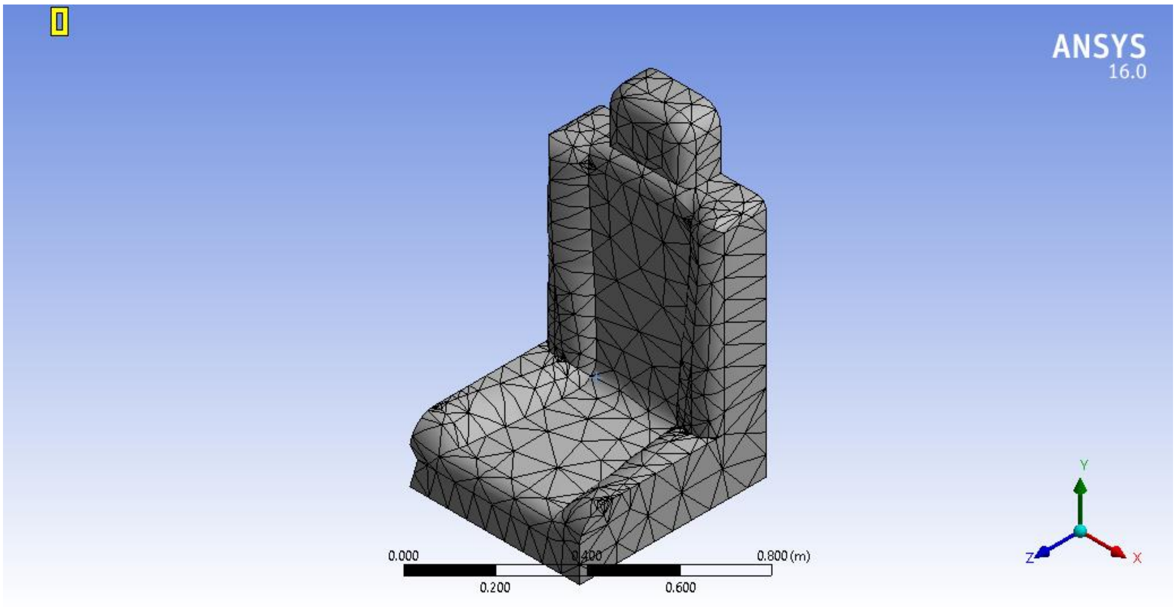


3.3.2 Data Input

Input of the data are based on the literature review. As for the car seat, assume the material is resin polyester. Since the car seat undergoes harmonic motion, the harmonic response is chosen from the analysis system.

The most important part in ANSYS is setting the mesh. It is to allow the software generate and analysis the solution of the geometry. The coarse mesh is set up for this geometry. Diagram below shows the result:

Diagram 4: Result from the meshing

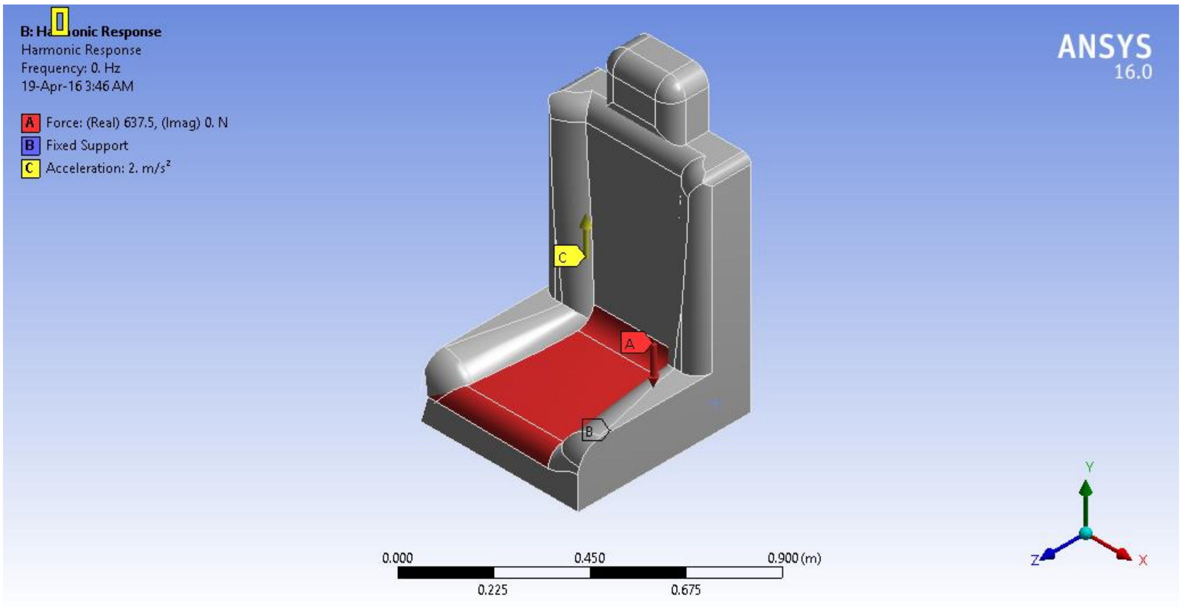


After the meshing is done, the mechanical simulation data is to be put into the geometry. Three mechanical loads are put on the geometry is the weight of the driver, rms (root mean square) acceleration of the harmonic motion and the fix support beneath the seat. On top of that, the range of frequency also set to for the input.

The constant mechanical load for weigh is 65 kg (637.5N) is put on the seat, hence the seat is assuming to be human effected by the vibration. For the variable mechanical load, rms acceleration is 0.3 m/s^2, 1 m/s^2, 2 m/s^2 is set as the range taken from the table 3. 1-10 Hz are choose for the frequency range input as follow table 1.

Diagram below show the input from the ANSYS Multiphysics:

Diagram 5: Input result



After all the inputs is set, the simulation of the geometry begin from this point and the output solution and result is analyze.

4. Result and Discussion

The results of the simulation obtain from the ANSYS for the car seat geometry is obtain. The simulation for 0.3 m/s^2 rms acceleration is shown below.

Table 5: Table for displacement at 0.3 m/s^2

Frequency (Hz)	Amplitude Displacement (m)
1	3.36E-08
2	3.36E-08
3	3.36E-08
4	3.36E-08
5	3.36E-08
6	3.36E-08
7	3.36E-08
8	3.36E-08
9	3.36E-08
10	3.36E-08

Diagram 6: Graph for displacement at 0.3 m/s^2

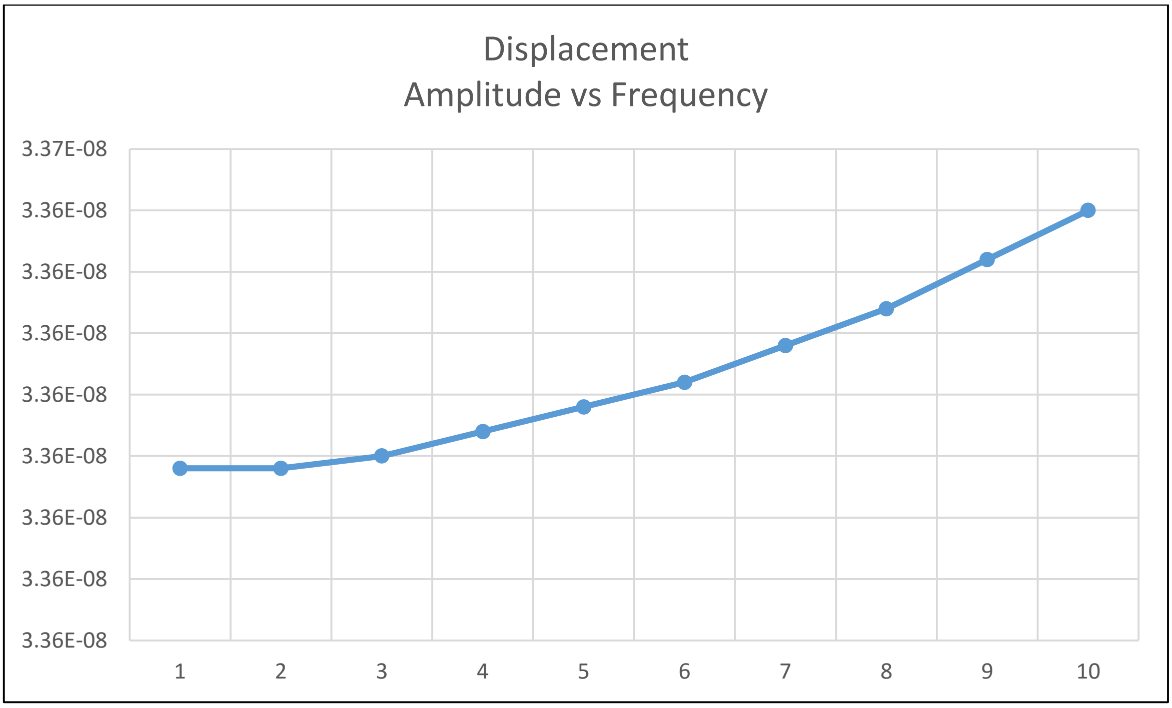
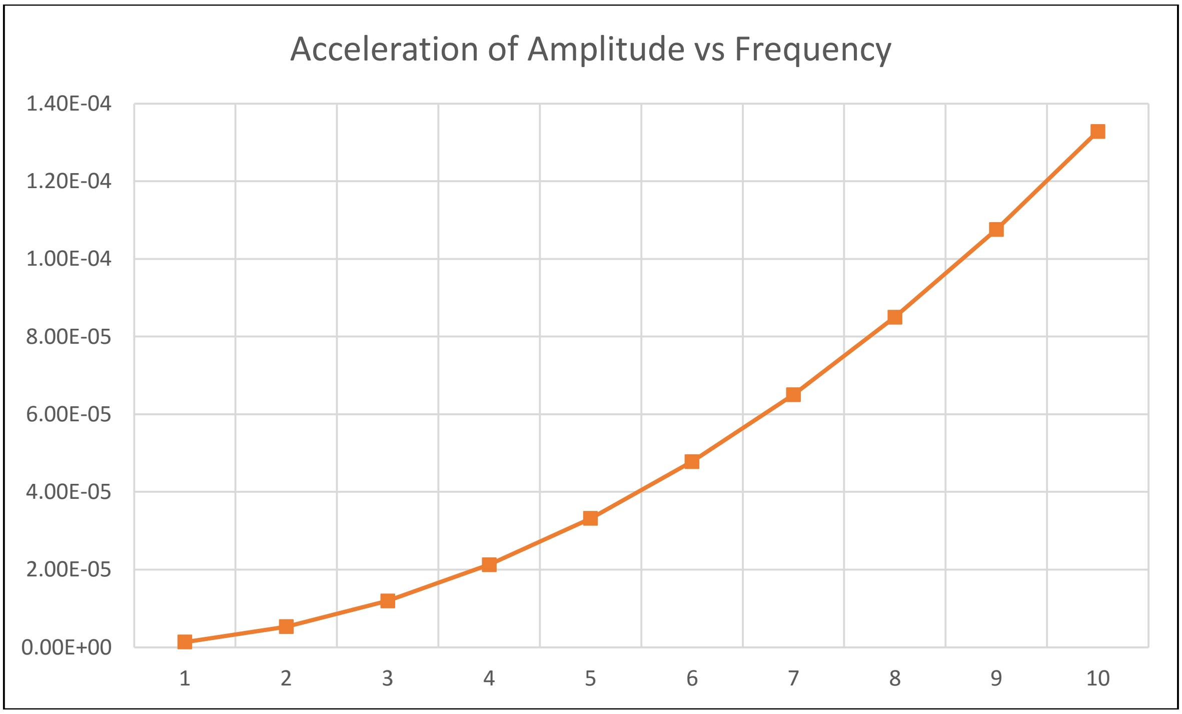


Table 6: Table for acceleration at 0.3 m/s^2

Frequency (Hz)	Amplitude Acceleration (m/s^2)
1	1.33E-06
2	5.31E-06
3	1.19E-05
4	2.12E-05
5	3.32E-05
6	4.78E-05
7	6.51E-05
8	8.50E-05
9	1.08E-04
10	1.33E-04

Diagram 7: Graph for acceleration at 0.3 m/s^2



The results from the displacement shows very little significance to the geometry around $3.36x10^{-8}$ m. Same goes to the acceleration, the change is insignificance to cause any harmful to human body.

For 1 m/s^2 rms acceleration, the result shows below

Table 7: Table for displacement at 1 m/s^2

Frequency (Hz)	Amplitude displacement (m)
1	5.99E-08
2	5.99E-08
3	5.99E-08
4	5.99E-08
5	5.99E-08
6	5.99E-08
7	5.99E-08
8	5.99E-08
9	5.99E-08
10	5.99E-08

Diagram 8: Graph for displacement at 1 m/s^2

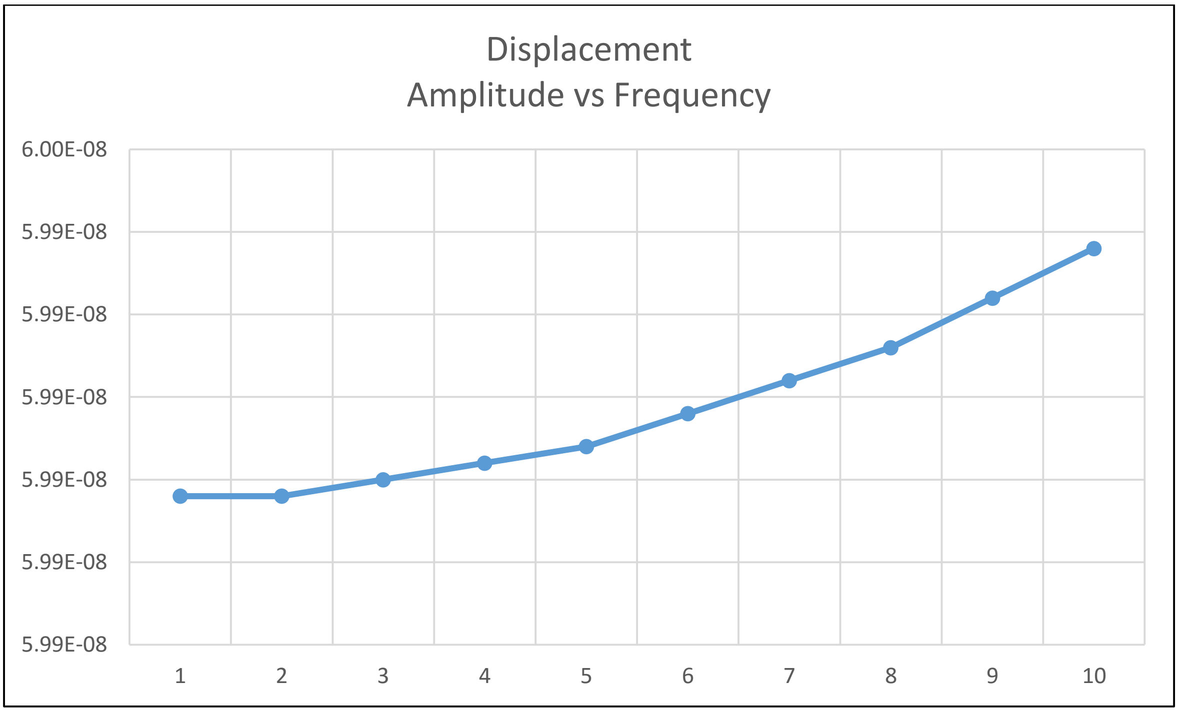
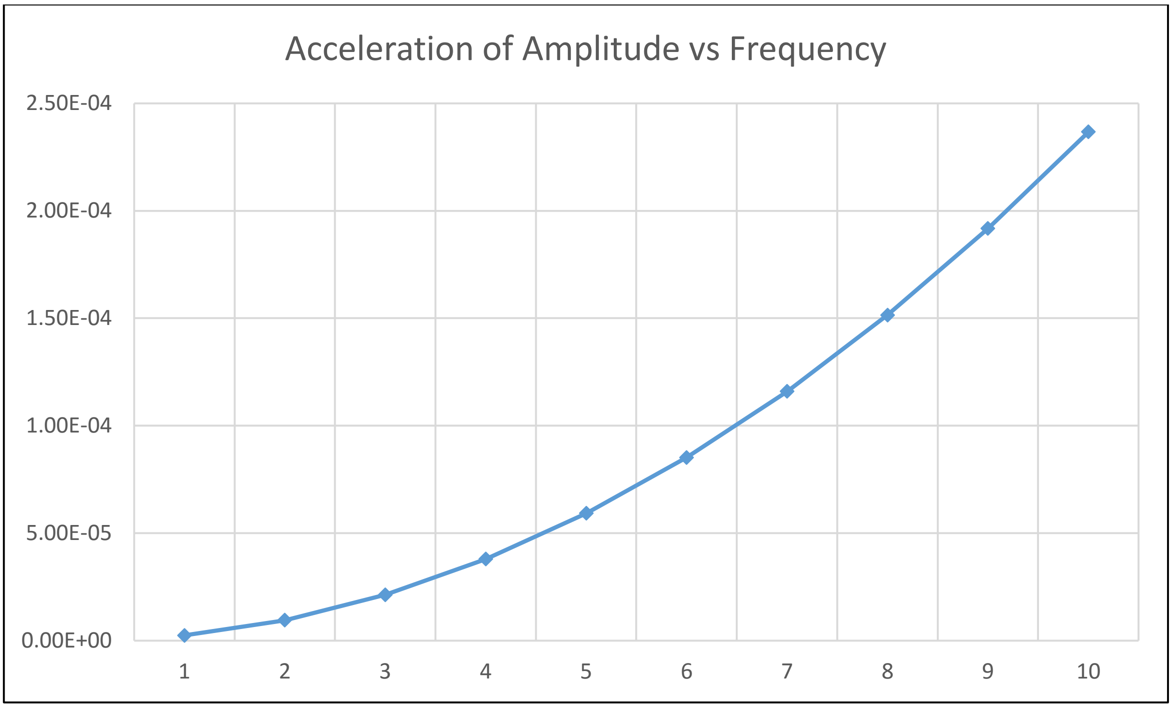


Table 8: Table for acceleration at 1 m/s^2

Frequency (Hz)	Amplitude Acceleration (m/s^2)
1	2.37E-06
2	9.46E-06
3	2.13E-05
4	3.79E-05
5	5.92E-05
6	8.52E-05
7	1.16E-04
8	1.51E-04
9	1.92E-04
10	2.37E-04

Diagram 9: Graph for acceleration at 1 m/s^2



The results from the displacement shows very little significance to the geometry around 5.99x10^{-8} m. The difference between the displacement is almost zero. Same goes to the acceleration, the change is insignificance to cause any harmful to human body.

For 2 m/s^2 rms acceleration, the result shows below

Table 9: Table for displacement at 2 m/s^2

Frequency (Hz)	Amplitude displacement (m)
1	9.75E-08
2	9.75E-08
3	9.75E-08
4	9.75E-08
5	9.75E-08
6	9.75E-08
7	9.75E-08
8	9.75E-08
9	9.75E-08
10	9.75E-08

Diagram 10: Graph for displacement at 2 m/s^2

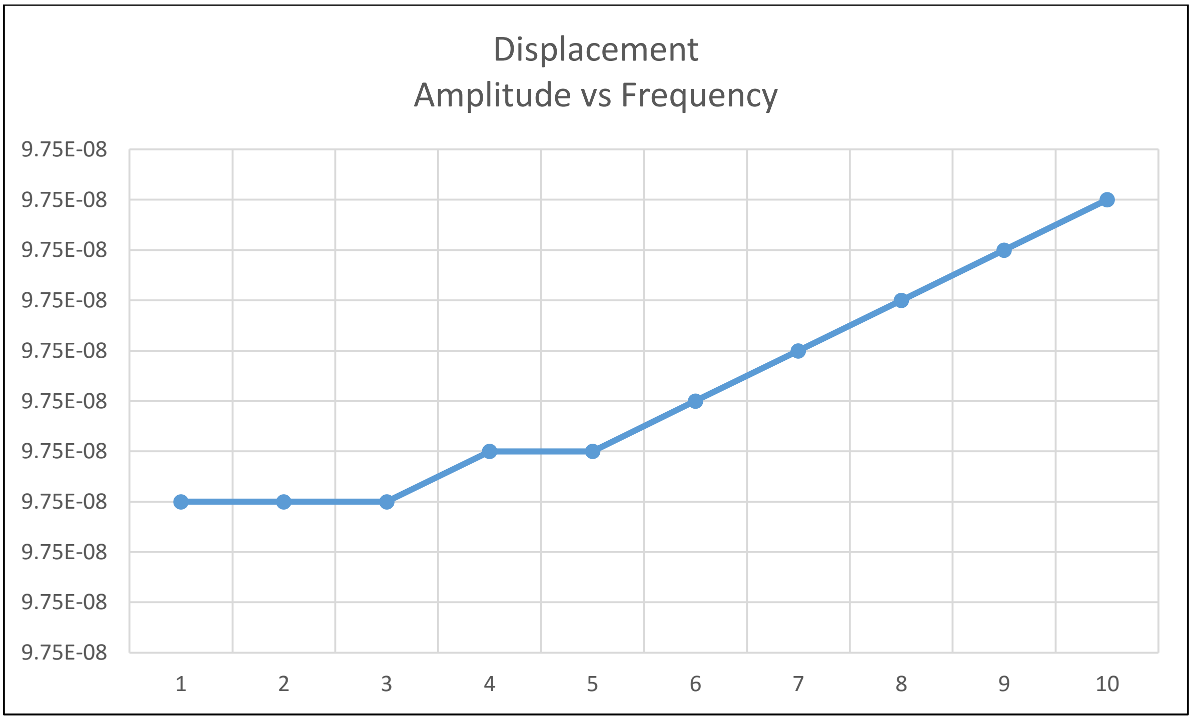
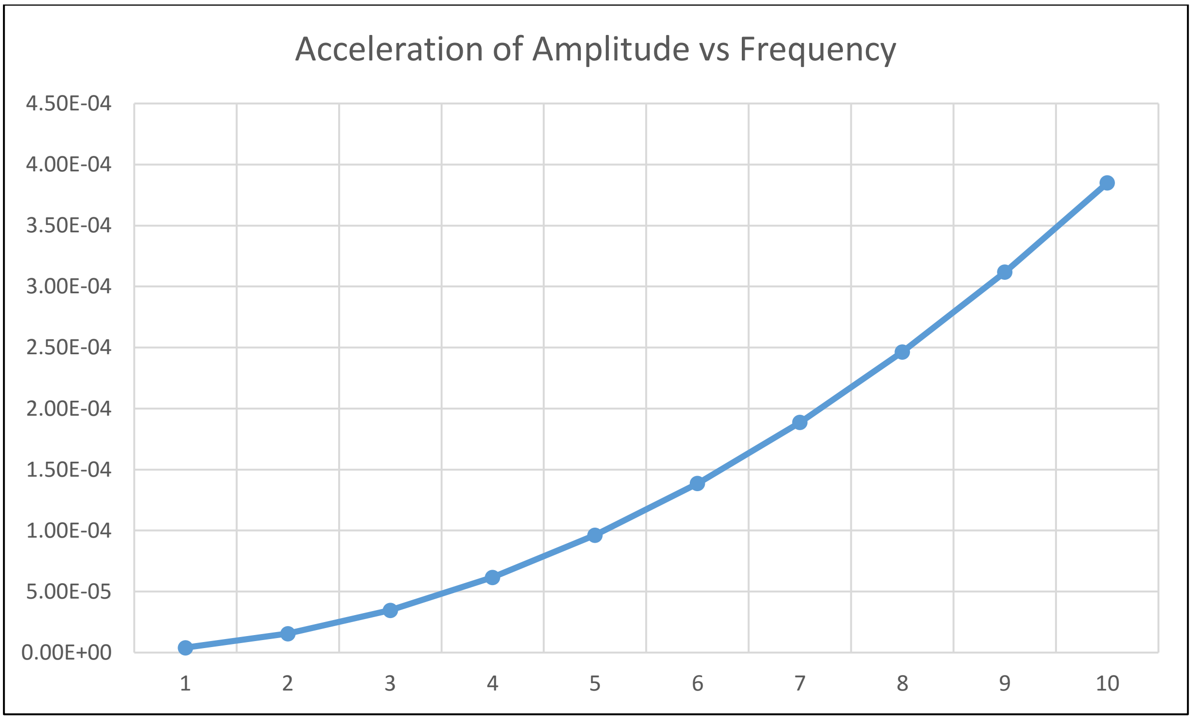


Table 10: Table for acceleration at 2 m/s^2

Frequency (Hz)	Amplitude Acceleration (m/s^2)
1	1.33E-06
2	5.31E-06
3	1.19E-05
4	2.12E-05
5	3.32E-05
6	4.78E-05
7	6.51E-05
8	8.50E-05
9	1.08E-04
10	1.33E-04

Diagram 11: Graph for acceleration at 2 m/s^2



The results from the displacement shows very little significance to the geometry around 9.75×10^{-8} m. The difference between the displacement is almost zero. Same goes to the acceleration, the change is insignificance to cause any harmful to human body.

5. Gantt Chart and Project Milestone

No.	Description	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project selection	■	■	■	■										
2	Preliminary project research				■	■	■								
3	Extended proposal submission							■	★						
4	Proposal defense									★					
5	Project work continuation									■	■	■	■		
6	Interim report submission (1st draft)													■	
7	Interim report submission														★

6. Conclusion

From the result that have been simulate, all of the results shows insignificance harmful to human body. From the ANSYS software itself we can use as a tools to gain more knowledge from the virtual world to get general knowledge of what might happened to the model we develop. This is essentials to avoid any insignificance damage to the model made. For example a car, high cost manufacturing may impact the development of company. In order to avoid any damage to the company, it’s safe to use virtual model as early development to get the general idea on how to choose the suitable material, cost budget, test provided, hazard, and etc.

From this project, the results show essential knowledge on developing the car seat. Since all of the result shows no any harmful to human bodies from the input rms acceleration. The car seat might be safe to manufacturing consider from the engineering views. In reality, it might not suitable because various factor need to be consider but from the software we can minimize the risk of the damage for what might happened in the future.

7. Recommendation

From the software we know it ease human difficulty and give us opportunity to minimize the risk of the damage either in business or human itself. Vibration is one of the important mechanical studies in engineering. High excitation vibration may cause harmful to human body, hence it’s important to control the vibration in order to achieve optimal comfortable to human and to avoid hazard to the surrounding.

Vibration can might be greatly reduce if apply the same concept as camera stabilization. Camera stabilization work by reducing and control the camera from shaking vigorously. It’s useful when using tele-lens or long range lens to control the shaking of the camera since the lens is long and big. If the concept is apply to car seat, it can greatly reduce the vibration energy, besides the occupant will be able to read a book comfortably.

9.0 References

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