CORRELATION STUDY OF THE STRAIN AND VIBRATION SIGNALS OF A BEAM

HAMIZATUN BINTI MOHD FAZI

UNIVERSITY MALAYSIA PAHANG

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HAMIZATUN BINTI MOHD FAZI

Thesis submitted in fulfillment of the requirements
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FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled "*Correlation Study Of The Strain and Vibration Signals Of A Beam*" is written by *Hamizatun Binti Mohd Fazi*. I have examined the final copy of this report and in my opinion, it is fully adequate in terms of language standard, and report formatting requirement for the award of the degree of Bachelor of Mechanical Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering.

Dr. Mohd Fairusham B.Ghazali
Examiner Signature

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature:
Name of Supervisor: NURAZIMA BINTI ISMAIL

Position: LECTURER

Date: JUNE 2013

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree is not concurrently submitted for award of other degree.

Signature:
Name: HAMIZATUN BINTI MOHD FAZI

ID Number: MA09057

Date: JUNE 2013

Dedicated to my beloved parents, family, and friends

Thank you so much for always being there for me.

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CORRELATION STUDY OF THE STRAIN AND VIBRATION SIGNALS OF A BEAM

ABSTRACT

This work presents the correlation of study of the strain and vibration signal of a beam. This can be achieved by using the forced vibration experiment of a beam which conducted simultaneously with the used of strain gauge on the beam. The focus for this research is on the application of the beam which is commonly used in industry. From the other researcher, the correlation study of the strain and vibration signal is made using Hybrid Kurtosis method which focused on a coil spring differ from this research which be done using a beam.This work involved few steps, firstly, collecting data from the force vibration experimental method, followed by the statistical analysis using Matrix Laboratory (Matlab), Fast Fourier Transform (FFT) and lastly application of Marc Patran software. The experiment performed by considering different frequencies from 10 Hz to 60 Hz. For the statistical analysis, the parameter that used in this analysis are the mean, root mean square (r.m.s), standard deviation, variance, skewness and the kurtosis. By using the analysis, the correlation can be made by the time series data and frequency data. Marc Patran is used to find the analysis on the strain and the displacement of the beam. Displacement used as parameter of the vibration signal. As a result, it was found that the strain signal was linearly proportional to the vibration signals.

KAJIAN PERKAITAN ANTARA ISYARAT KETEGANGAN DAN GETARAN ALANG

ABSTRAK

Kajian yang dilakukan ini ialah mengenai perkaitan antara isyarat ketegangan dan isyarat getaran alang. Ini boleh dicapai dengan menggunakan eksperimen getaran paksa alang yang dijalankan serentak dengan menggunakan tolok tekanan pada alang. Tumpuan kajian ini ialah penggunaan alang yang biasa digunakan dalam industri. Menurut kajian penyelidik yang lain, kajian perkaitan antara isyarat ketegangan dan isyarat getaran dibuat menggunakan kaedah kurtosis hibrid yang memberi tumpuan pada lingkaran spring dan ianya berbeza daripada kajian ini yang dilakukan dengan menggunakan alang. Kajian ini melibatkan beberapa langkah, pertamanya, mengumpul data isyarat melalui kaedah eksperimen, diikuti dengan analisis statistic menggunakan *Matrix Laboratory (Matlab), Fast Fourier Transform (FFT)* dan aplikasi perisian *Marc Patran*. Eksperimen yang dilakukan menggunakan frekuensi yang berbeza dari 10 Hz hingga 60 Hz. Untuk analisis statistik, parameter yang digunakan dalam analisis ini adalah min, min punca kuasa dua, sisihan piawaian, varian, kepencongan dan kurtosis. Dengan menggunakan analisis, perkaitan boleh dibuat dengan data siri masa dan data kekerapan. Marc Patran digunakan untuk mencari analisis pada tekanan dan anjakan alang. Keputusan yang diperoleh mendapati bahawa isyarat ketegangan berkadar linear dengan isyarat getaran.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter provides the overview of the strain and the vibration signals. The background of the research be described and followed by the problem statement. This followed by the objective and scope of the study which perform the fatigue life analysis by the laboratory testing to collect strain and vibration signals.

1.2 STRAIN AND VIBRATION SIGNAL

The response of a system to an applied stress is called strain. The stress produces by the loaded force on a material caused the material to deform and the amount of the deformation in the direction of the applied force divided by the initial length of the material is called engineering strain The measure of the amount of strain being endured by a material is necessary in the various fields of engineering and applied science. This is because, from the measurement, the modulus of elasticity and Poisson’s ratio can be determined for a specific material then the properties are used to design an infinite number of highly stress and the critical component.

The study of motion of masses about its equilibrium position is called vibration. Strain oscillates within the elastic components due to vibration motion which results in fatigue stresses. The natural frequencies, corresponding mode shapes and damping are the three parameters that defined the dynamic characteristics of the vibration system. These three parameters will show the dynamic characteristics of the system and they are used in vibrational analysis.

1.3 RESEARCH BACKGROUND

Researchers believe that during the component or structure subjected to the loading, there were existences of strain and vibration signals on the same time which will contribute to mechanical failure of the component. The mechanical failure of the component will effect the safety and also the environment because it may cause big destruction of structure such as bridge, vehicle etc. Hence, strain and vibration signals are really necessary for this study in order to find the correlation between them which induced mechanical failure.

The strain and vibration signals measured on a beam were used as the subject for the study as the component directly experienced the load when the system is running. Statistical analysis is use for the analysis of this research.

1.4 PROBLEM STATEMENT

In various engineering field, it is very important to study about fatigue life and the vibration of the mechanical component because both of them relate to the mechanical failure of the component or structure. Fatigue failure is related to the strain applied on the component. From the previous researcher, they believe that mechanical failure of a beam caused by the fatigue failure. It has been estimated that fatigue contributes to approximately 90% of all mechanical service failures (ASM International, 2008). Fatigue failure occurs due to the repetitive cyclic stress that much lower than the stress needed to cause failure during a single application of stress. Other researcher, found that in service life, automotive suspension system experiences the significant load that cause vibration and displacement that contributing to mechanical failure through fatigue (S.Abdullah et al., 2007). Vibration is related to mechanical failure because it induced strain to oscillate then effect the fatigue life of the structure. Therefore, in order to reduce the possibility of the component to fail, it is really important to study the correlation of these two signals.

1.5 OBJECTIVE

The main objective of this study is to find correlation between the strain signals and the vibration signal.

1.6 SCOPE

The main purpose is to perform laboratory testing to collect strain and vibration signals. For this experiment, the software used is Dasylab which performed the both signals using Strain gauge, accelerometer, NI equipment and also simple beam. Besides, the aim is to perform fatigue life analysis by using Marc Patran software which can analyze the data. This study will perform correlation study to determine the relationship between these two signals.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter summarise all researched and worked that have been done by previous researchers. Fatigue damage assessment is described in section 2.2. Next, general review on vibration signal correlate to fatigue damage and previous works on the study of vibration and stain signals using Mathematical Programming Approach.

2.2 FATIGUE DAMAGE ASSESSMENT

For over 150 years, engineers have recognized that fatigue can cause metal to fail. When in-vehicle load measurement became available with analysis software and low-cost computers, modern fatigue analysis is introduced. Fatigue life is very important in most of engineering field as it is used to predict the life cycle of the mechanical structure which the majority of the mechanical components are being subjected to the variable loading.

Fatigue failures occur due to the application of fluctuating stresses that are much lower than the stress required to cause failure during a single application of stress. It has been estimated that fatigue contributes to approximately 90% of all mechanical service failures. Fatigue is a problem that can affect any part or component that moves. Automobiles on roads, aircraft wings and fuselages, ships at sea, nuclear reactors, jet engines, and land-based turbines are all subject to fatigue failures. Fatigue was initially recognized as a problem in the early 1800s when investigators in Europe observed that bridge and railroad components were cracking when subjected to repeated loading. As the century progressed and the use of metals expanded with the increasing use of machines, more and more failures of components subjected to repeated loads were recorded. Today, structural fatigue has assumed an even greater importance as a result of the ever-increasing use of high-strength materials and the desire for higher performance from these materials (ASM International, 2008).

There are three basic factors necessary to cause fatigue:

- A maximum tensile stress of sufficiently high value
- A large enough variation or fluctuation in the applied stress
- A sufficiently large number of cycles of the applied stress.

Fatigue under such loading involving stresses along more than one axis is known as multiaxial fatigue (Garud Y.S,1981). The fatigue life is the number of cycles to failure at a specified stress level, while the fatigue strength (also referred to as the endurance limit) is the stress below which failure does not occur (ASM International,2008).

Strain can be measured and has been shown to be excellent parameter for correlating fatigue life (D. Ramesh, 2003). Fatigue behavior of a material is generally conceived by its S-N (amplitude stress versus life) characteristics. An equivalent fatigue life parameter is thrived under multi axial loadings, rather than the amplitude stress. Successful stress based multi axial fatigue damage parameter have the general form

$$\sigma_{eq} = \Delta\,\tau + k\sigma_n \tag{1}$$

There are three major approaches have widely been used to analyses fatigue damage or fatigue life, namely the stress-life approach (*S-N*), the strain-life approach (*ε-N*) and the linear elastic fracture mechanics (*LEFM*) (R. I. Stephens et al., 1997). As the case study was related to low cycle fatigue, the strain-life approach (*ε-N*) is used for the analysis, because it is a suitable approach to analyses random data collected from the experiment. For ductile material at relatively short fatigue lives, strain-life approach is often used and it is also use at long fatigue life of little plasticity.

2.3 GENERAL REVIEW ON VIBRATION SIGNAL CORRELATE TO FATIGUE DAMAGE

From the past experience, its show that the other common factor which causes the mechanical failure under dynamic force is vibration. Vibration involves the motion of masses about its equilibrium position. During the vibratory motions, the strain oscillates within the elastic components and leads to fatigue stress then cause the mechanical failure of the component. Vibration system has its dynamic characteristics which consist of natural frequencies, the component mode shapes and damping. Its dynamic characteristics can be defined based on these three parameters and it is use for vibration analysis.

The component modes shapes which is one of the vibration system dynamic characteristics caused displacement to the component (W.Scott, 1999).

There are two part of solution in vibration consist of complimentary solution and particular solution. For complimentary, RHS become zero when the system is in free vibration and the response is called transient response. The other one is particular solution, RHS = external excitation for P which is when the system in force vibration and the response is called steady-state response.

The resonance which resulted from the vibratory motion is very serious amplification as its causes large fatigue stress. Therefore, in many applications, it is not only focusing on the investigation of the fatigue resisting properties of material and the parts under known excited stress but the investigation must includes the capability of the part to endure the known exciting force at resonance.

For one degree of freedom forced vibration below, it shows the resonance of a system (Timoshenko et al., 1990) ;

By considering the steady state component, when the system is acted upon by an excitation force F = P sinωt :

$$\sum F = 0$$

$$kx + m\frac{d^2x}{dt^2} = P\sin\omega t \qquad (2.3.1)$$

$$x = A\sin\omega t$$

$$kA\sin\omega t - m\omega^2\sin\omega t = P\sin\omega t$$

$$A = \frac{P}{k - m\omega^2} \qquad (2.3.2)$$

Figure 2.3(a) shows the direction of the parameter which are spring stiffness, inertia force and external force when the object being compressed using force, F in the direction of x.

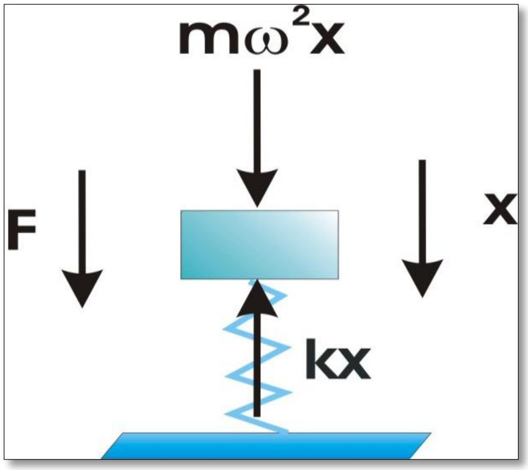


Figure 2.3 (a) A system undergo force vibration

Figure 2.3(b) shows condition when the frequency of excitation increasing from zero (ω=0) :

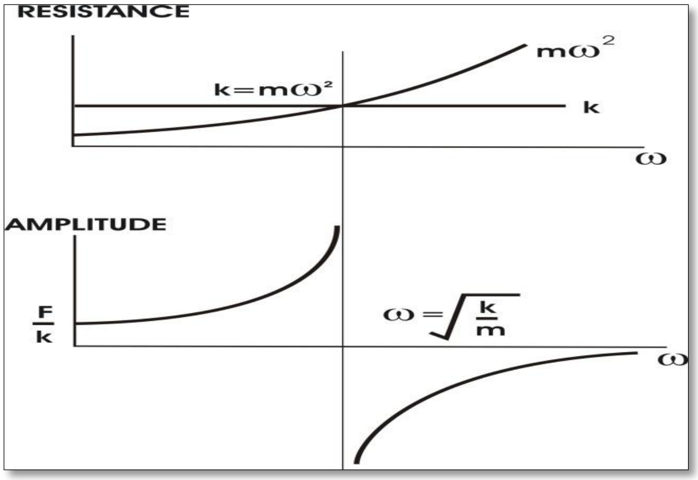


Figure 2.3(b) Condition when frequency of excitation increase from zero

i) At low frequency when natural frequency,$\omega \sim 0$

Inertia resistance, $\omega^2 m \sim 0$

At this instant, motion is controlled by stiffness, k.

Stiffness Controlled.

$$A \sim P/k \tag{2.3.3}$$

ii) From low frequency to resonance

Stiffness resistance is constant with respect to frequency. As the excitation frequency is increased, the inertia resistance will also increase and it will come to an instant where the inertia resistance will cancel the stiffness resistance ($m\omega^2=k$). As a result, the excitation force,F will now act on the mass without any resistance. This will cause the mass to oscillate with large amplitude. If this oscillation is allowed to continue, the amplitude will get larger until it is restricted by damping, non-linearity or part of the system will break. This condition is called resonance. The frequency at this instant is called natural frequency.

$$\omega_0 = \sqrt{\frac{k}{m}} \tag{2.3.4}$$

iii) After resonance

If the frequency is increased further, the inertia resistance will overcome the stiffness resistance. Displacement, x is out of phase with force, F. The magnitude of oscillation will become small until a point where the motion is controlled by the mass m (mass controlled). The system is said to be in isolation.

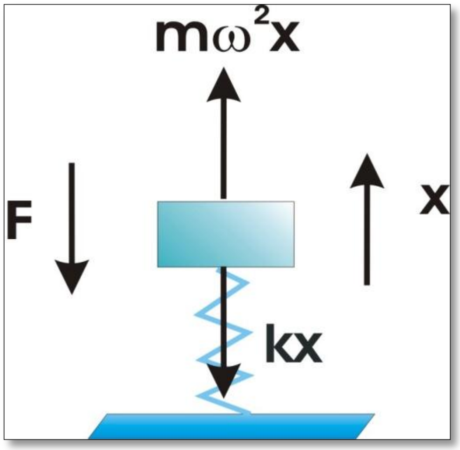


Figure 2.3(c) A system undergo force vibration of single degree of freedom

Considerable work has been done on the fatigue and other properties of materials which define their ability to withstand specified excited cyclic stress produced by either resonant or other vibrations. However, comparatively little has been done on the analysis of the properties of materials and other factors which determine their ability to withstand specified resonance exciting force.

The amplification in vibration that is caused by resonance has not received its due attention. Consequently, the research is concerned not with fatigue alone, but with both fatigue and damping capacity as joint criteria for defining the ability of a part to withstand resonant vibrations. There has been some service experience to indicate that fatigue strength alone does not provide a sole basis for judging materials, parts, or structures exposed to resonant vibrations. For example, under the resonant vibrations excited by wind, a copper overhead cable of relatively low tensile and fatigue strengths but high damping capacity may be more durable than a light high-strength alloy having lower damping capacity (Lazan,1954).

2.4 STATISTICAL ANALYSIS

According to Meyer (1993), a signal is a series of numbers or data that come from any measurement, typically obtained using some recording method as a function of time. Many signals in nature exhibit random or nondeterministic characteristics which provide a challenge to analyse using signal processing techniques (Tacer et al., 1998). Mechanical signals can be classified to have stationary or non-stationary behavior in actual applications. The behavior that the statistical property values remained unchanged with the changes in time is called stationary signal while the statistical parameter values of a signal which dependent to the time of measurement is non-stationary signal. For both stationary and non-stationary signal, the engineering-based signal analysis is important to explore the characteristics and behaviour of the signal, and the outcomes of these can also related to the fault detection and analysis (Giacomin et al., 1999).

The global signal statistics are frequently used to classify random signals and the most commonly used statistical parameters are the mean value, the standard deviation value, the root-mean-square (r.m.s.) value, the skewness and the kurtosis (Hinton, 1995). Statistic analysis had been performed in order to achieve the objective of this paper. Both strain and vibration signals were analysed using the statistical analysis and Fast Fourier Transform (FFT).

The value of the global signal statistical parameters characterised a stationary signal such as the mean, variance and root-mean-square which unchanged across the signal line . For a signal with a number of data points in the sampled sequence n, the mean value $\bar{x}$, is given by :

$$\bar{x} = \frac{1}{n}\sum_{j=1}^{n} x_j \qquad (2.4.1)$$

The standard deviation (SD) is mathematically defined as

$$SD = \left\{\frac{1}{n}\sum_{j=1}^{n}\left(x_j - \bar{x}\right)^2\right\}^{\frac{1}{2}} \qquad (2.4.2)$$

For the samples more than 30. If the samples less than 30, the standard deviation is defined as (Hinton 1995) :

$$SD = \left\{\frac{1}{n-1}\sum_{j=1}^{n}\left(x_j - \bar{x}\right)^2\right\}^{\frac{1}{2}} \tag{2.4.3}$$

The standard deviation value measures the spread of the data about the mean value. The r.m.s. value, which is the 2nd statistical moment, is used to quantify the overall energy content of the signal. For discrete data sets the r.m.s. value is defined as

$$r.m.s = \left\{\frac{1}{n}\sum_{j=1}^{n} {x_j}^2\right\}^{\frac{1}{2}} \tag{2.4.4}$$

For a zero-mean signal the r.m.s. value is equal to the SD value. The skewness, which is the signal 3rd statistical moment, is a measure of the symmetry of the distribution of the data points about the mean value. The skewness of a signal is given by

$$S = \frac{1}{n(r.m.s)^3}\sum_{j=1}^{n}\left(x_j - \bar{x}\right)^3 \tag{2.4.5}$$

The skewness for a symmetrical distribution such as a sinusoid or a Gaussian random signal is zero. Negative skewness values indicate probability distributions that are skewed to the left, while a positive skewness values indicate probability distributions that are skewed to the right, with respect to the mean value.

Kurtosis, which is the signal 4th statistical moment, is a global signal statistic which is highly sensitive to the spikiness of the data. For discrete data sets the kurtosis value is defined as equation (2.4.6)

$$K = \frac{1}{n(r.m.s)^4} \sum_{j=1}^{n} \left(x_j - \bar{x}\right)^4 \qquad (2.4.6)$$

For a Gaussian distribution the kurtosis value is approximately 3.0. Higher kurtosis values indicate the presence of more extreme values than should be found in a Gaussian distribution. Kurtosis is used in engineering for detection of fault symptoms because of its sensitivity to high amplitude events (Qu and He 1986).

The crest factor, which is commonly encountered in engineering applications, is defined as the ratio between the maximum value in the time history and the r.m.s. value:

$$CF = \left|\frac{x_{j\,max}}{r.m.s}\right| \qquad (2.4.7)$$

The crest factor value for sinusoidal time histories is 1.41 and the value approaches 4.00 in the case of a Gaussian random signal of infinite length.

2.5 FAST FOURIER TRANSFORM (FFT)

Mathematical method for transforming a function of time into a function of frequency is called as Fast Fourier Transform (FFT). Besides, it also represent transform as transforming from the time domain to the frequency domain. It is very beneficial for analysis of time-dependent case.

A frequency analysis result’s commonly be depicted by means of graph having frequency on the x-axis and amplitude on the y-axis. Fourier transform is the algorithm that is used to split the time history into its constituent sinusoidal components . French mathematician and engineer Jean Baptiste Joseph Fourier was the first defined this transform. They are the one who postulated that any periodic function could be expressed as the summation of sinusoidal waves of varying frequency, amplitude and phase. The review of a signals based on amplitude frequency and phase of its component sinusoids are the way to understand the spectral analysis. A frequency of periodic time function, x(t), analysis can be performed using the classical Fourier transform defined by the mathematical definition:

$$X(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} x(t)e^{-i\omega t}dt \qquad (2.5.1)$$

where X(ω) is the amplitude of Fourier transform in frequency distribution, ω is the angular frequency and $i = \sqrt{-1}$.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter described about the step or method conducting the experiment. There are including project flows which show the overall steps for this experiment starting from the setting of the software until data analysis. Then, following by the experiment setups, which introduced the equipment and software involved. The last part is the procedure of the experiment which is the part where the explanation about the steps in software setting, experiment conducted until collecting data. Figure 3.1 shows the overall methodology of the proposed techniques. Each of the steps is explain next in this text.

Process Flow Of Experimental Process

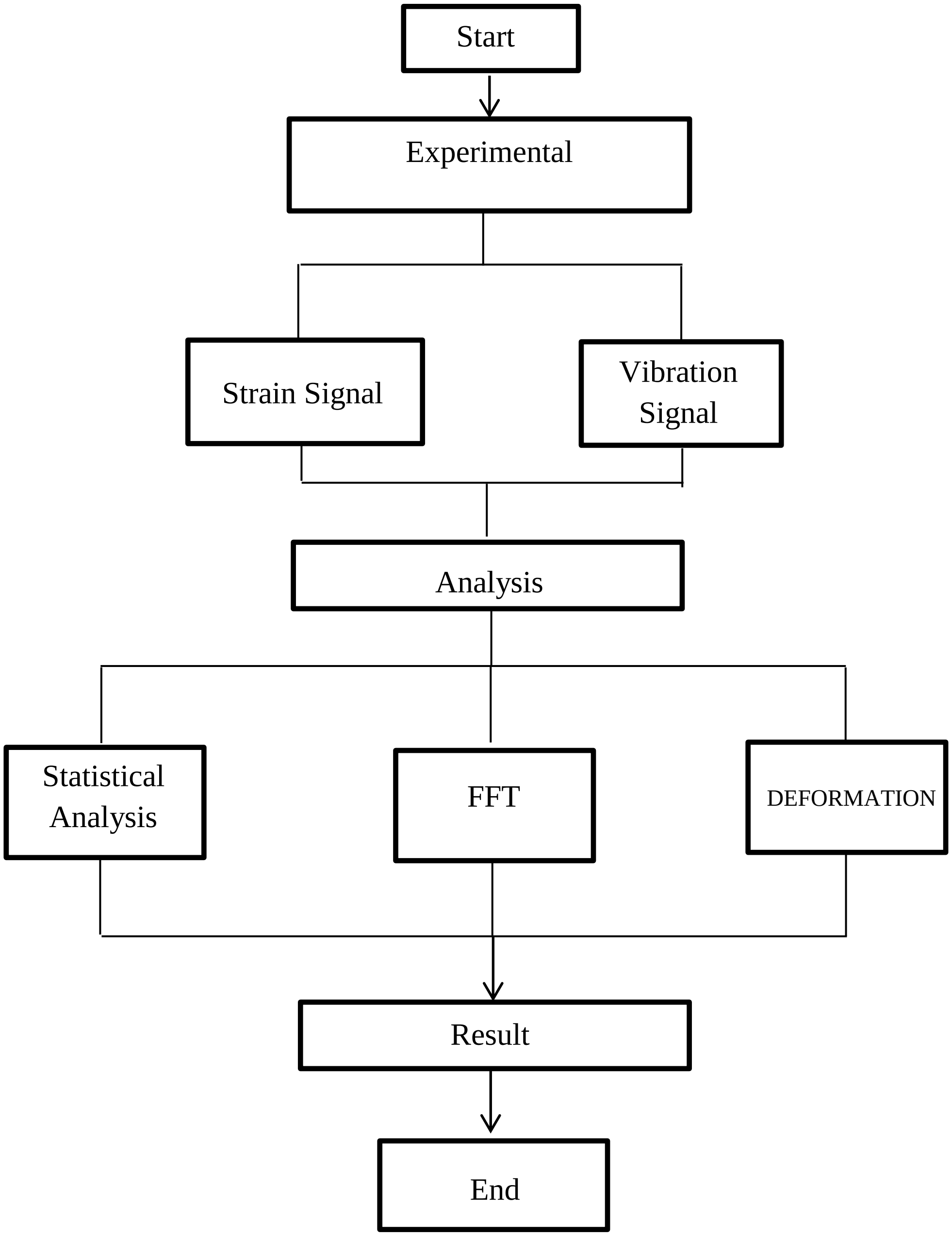


Figure 3.1: Process flow of experimental process

3.2 METHODOLOGY

Correlation between strain signal and vibration signal is obtained by four steps. The first step is collecting strain signals and vibration signals by doing an experiment followed by the analysis. The first analysis is Fast Fourier Transform (FFT) using dasylab then followed by the statistical analysis using Matrix Laboratory (Matlab). The next step is using the Design Life software to find the fatigue life.

3.2.1 STEP 1 : EXPERIMENTAL DATA

3.2.1.1 Experiment Setup For The Hardware

For experiment setup of the hardware, the equipment use as follows:

1. Accelerometer
2. Strain gauge
3. National Instrument (NI)
4. Personal Computer (PC)

Steps for Experiment Setup:

1. The test rig for the experiment shown in Figure 3.2.1.1(a)
2. Put the strain gauge and the accelerometer at the center of the beam as shown in Figure 3.2.1.1(b).

3. Connect the accelerometer and the strain gauge to the NI instruments as shown in Figure 3.2.1.1 (c).
4. Connect the NI instrument to the PC.

Note that, in Figure 3.2.1.1(c), the green wire is used to make a by pass for the strain gauge in channel 0.

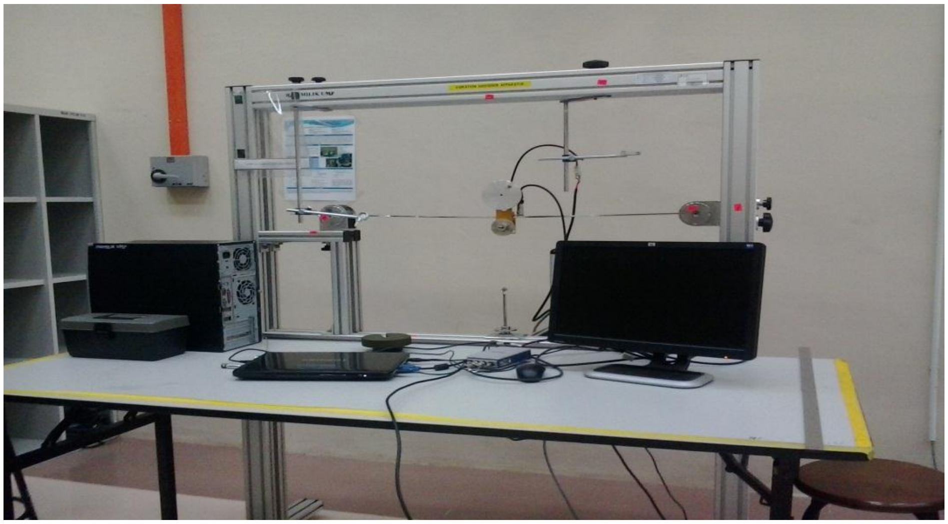


Figure 3.2.1.1(a) The test rig for the experiment

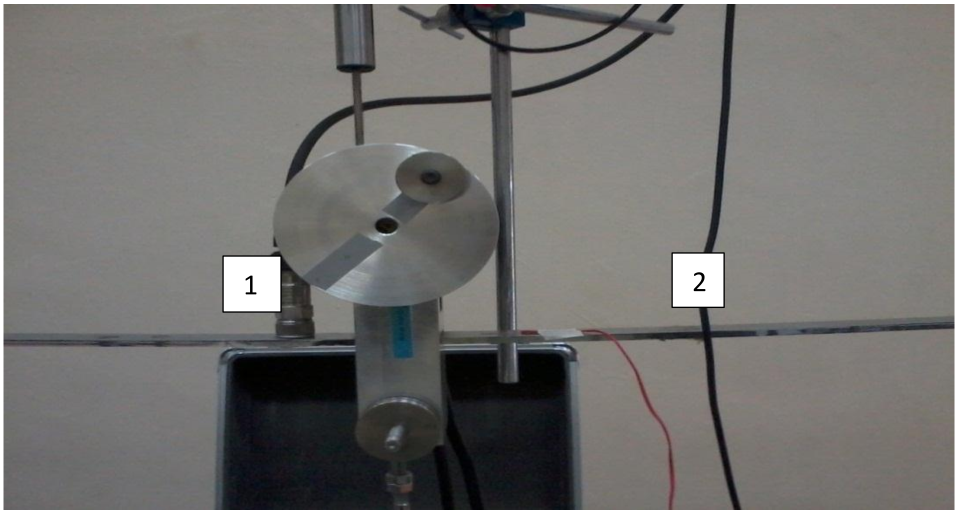


Figure 3.2.1.1(b) Connection of strain gauge and the accelerometer to the beam

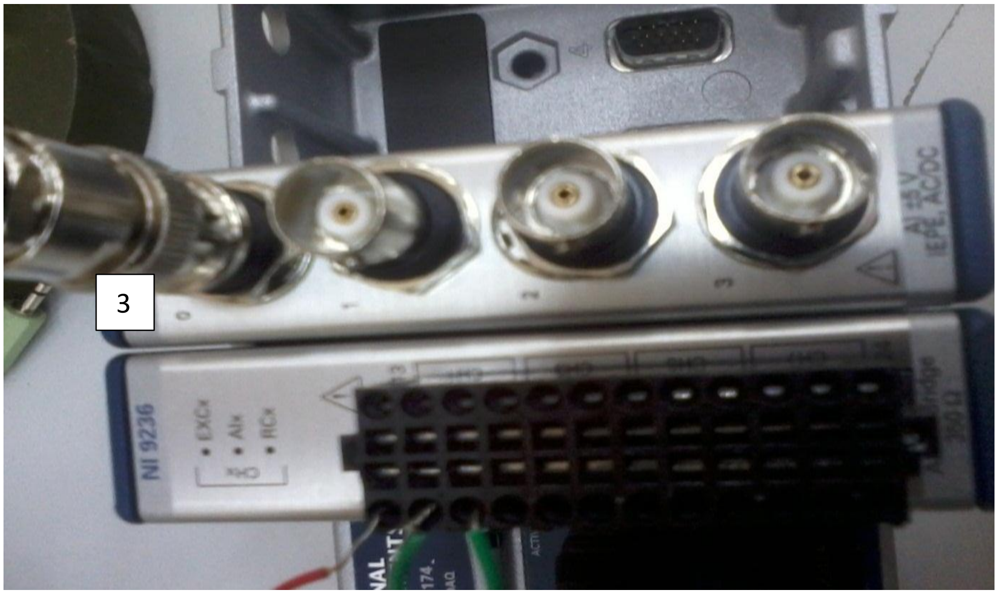


Figure 3.2.1.1(c) Connection strain gauge and the accelerometer to the NI instrument

Figure 3.2.1.1(d) Connection on NI-DAQ Max to the accelerometer and strain gauge

3.2.1.2 Experiment procedure for the software

The software use as follow:

1. Measurement and Automation Explorer.
2. Data Acquisition System (DASYLab)

Measurement and Automation Explorer.

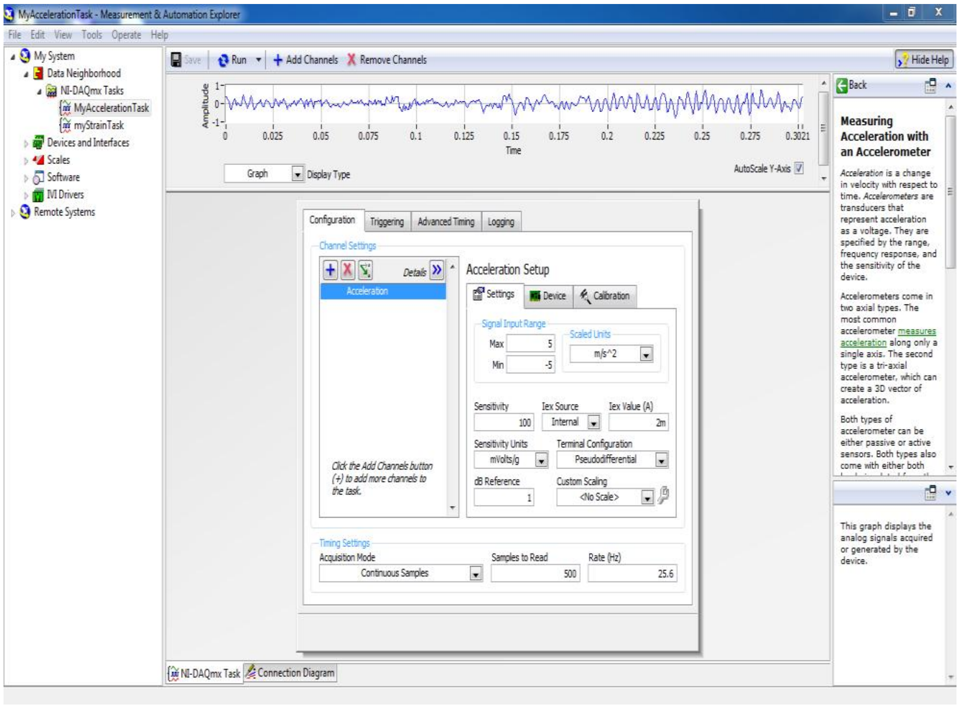
Measurement and Automation Explorer (MAX) is the software which provides access to National Instrument (NI) such as CAN, DAQ and IMAQ. By using this software the National Instruments hardware and software can be configured. It also can be use to create and edit channel tasks, interfaces, scales and virtual instruments. Besides, this software can execute system diagnostics and run test panels. Therefore, this software can view devices and instruments connected to the system.

For this experiment, the MAX is access to National Instrument which is DAQ. There are two parameters that used in this experiment which is strain and acceleration which means that two channel being used. Figure 3.2.1.2 (a) show the details that need to be adjust in measurement and automation explorer software for acceleration task while Figure 3.2.1.2 (b) show the details that need to be adjust for strain task. A few steps to be done for this experiment which is start from the setting of the NI instrument after the experimental equipment being setup.

For the setting of the National instrument, the steps as follows:

1. Double click on the icon on the desktop. This will open up a window. The configuration window on the left contains a Data Neighborhood icon.
2. Right click on this icon and select Create New.
3. Left click on NI-DAQmx Global Virtual Channel and click next.
4. Select “Generate Signals”, then select Analog Output, and select (strain or acceleration).
5. New window will pop up.
6. The DAQ hardware we are using is Device 1
7. Select the appropriate channel and click Next.
8. Name the channel Analog Channel 01, click through description, and then click Finish

Note that, for different parameter (strain and acceleration), make a new setting in Measurement and Automation Explorer (MAX).



Signal Input Range: Max 5, Min -5

Scaled Units: m/s^2

Sensitivity: 100

Iex Source: Internal

Iex Value (A): 2m

Sensitivity Units: mVolts/g

Terminal Configuration: Pseudodifferential

dB Reference: 1

Custom Scaling: <No Scale>

Click the Add Channels button (+) to add more channels to the task.

Timing Settings

Acquisition Mode: Continuous Samples

Samples to Read: 500

Rate (Hz): 25.6

Measuring Acceleration with an Accelerometer

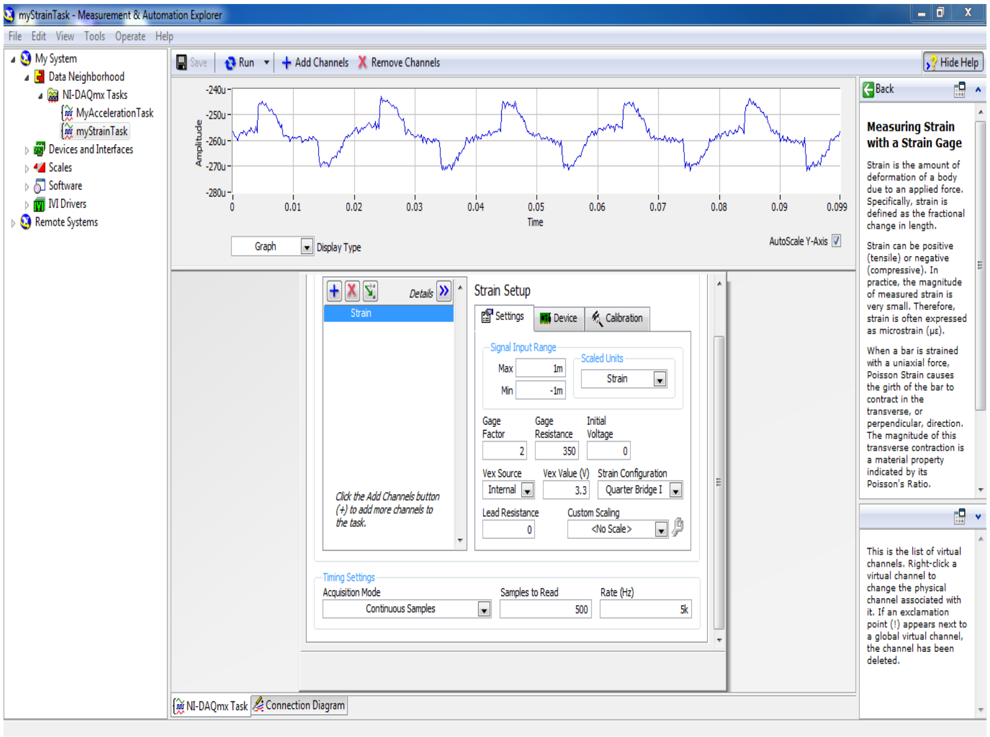
Acceleration is a change in velocity with respect to time. *Accelerometers* are transducers that represent acceleration as a voltage. They are specified by the range, frequency response, and the sensitivity of the device.

Accelerometers come in two axial types. The most common accelerometer measures acceleration along only a single axis. The second type is a tri-axial accelerometer, which can create a 3D vector of acceleration.

Both types of accelerometer can be either passive or active sensors. Both types also come with either both

This graph displays the analog signals acquired or generated by the device.

Figure 3.2.1.2(a) Setting for strain in Measurement and Automation explorer software



Strain Setup

Signal Input Range
Max 1m
Min -1m

Scaled Units
Strain

Gage Factor 2
Gage Resistance 350
Initial Voltage 0
Vex Source Internal
Vex Value (V) 3.3
Strain Configuration Quarter Bridge I
Lead Resistance 0
Custom Scaling <No Scale>

Timing Settings
Acquisition Mode Continuous Samples
Samples to Read 500
Rate (Hz) 5k

Click the Add Channels button (+) to add more channels to the task.

Measuring Strain with a Strain Gage

Strain is the amount of deformation of a body due to an applied force. Specifically, strain is defined as the fractional change in length.

Strain can be positive (tensile) or negative (compressive). In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as microstrain (με).

When a bar is strained with a uniaxial force, Poisson Strain causes the girth of the bar to contract in the transverse, or perpendicular, direction. The magnitude of this transverse contraction is a material property indicated by its Poisson's Ratio.

This is the list of virtual channels. Right-click a virtual channel to change the physical channel associated with it. If an exclamation point (!) appears next to a global virtual channel, the channel has been deleted.

Figure 3.2.1.2(b) Setting for vibration in Measurement and Automation explorer software

Figure 3.2.1.2 The setting of the Measurement And Automation Explorer

Next, open the Dasy lab software then synchronize with the measurement and automation explorer data (NI-DAQmx) before creating a module as shown in Figure 3.2.1.2(c) for collecting data from the experiment.

Data Acquisition System (DASYLab)

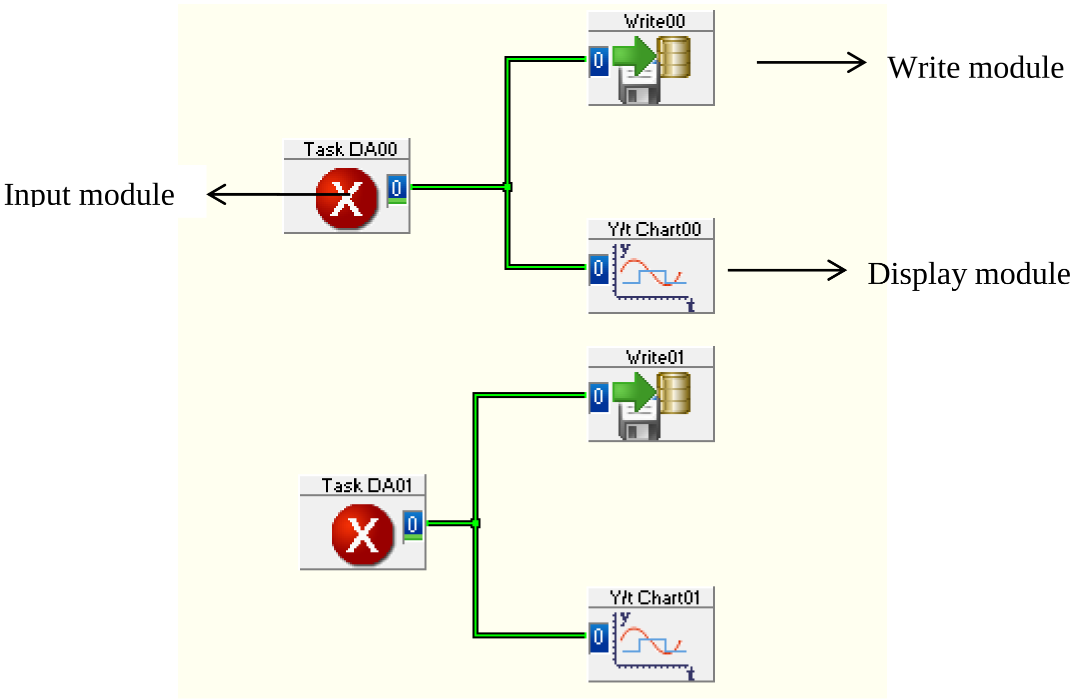


Figure 3.2.1.2 (c) The module setup in Data Acquisition System

The Module that being use for the experiment and its explanation as follow:

Input Module

This module inserts the connection between DASYLab and the analog input channels of the installed data acquisition hardware onto the worksheet. It uses the installed data acquisition driver to access the hardware. The data acquisition device will acquire data. The measured values are sent to the program using the module outputs of the module.

If the selected driver supports more than one hardware component, a Hardware Selection window opens displaying the available hardware. Select the hardware from the list to assign it to the new module.

Write Data Module

Write Data module used to save data channels and header information in files. DASYLab can write the data formats ASCII, DASYLab, DADiSP, DAP vector, DIAdem DAT, DIAdem TDM, Famos, Flex4, IEEE-32-Bit, nSoft, Remus, and Signalys DOS.

DASYLab checks whether at least 64 KByte free memory space is available on the selected storage medium. If DASYLab fills the storage medium completely during a measurement, DASYLab aborts the measurement and displays an error message. For this experiment, the data is saved in ASCII format.

Display module (Y/t Chart)

Y/t Chart module is used to display data channels as curves over time. The Y/t chart plots the curve in the Display window from the left to the right. The display window has a menu bar and a function bar to change, to survey, or to output the display during the measurement.

Use the Y/t Chart module to display data acquired in the kilohertz range. You cannot display FFT data and histogram data, and triggered data and non-triggered data together in one display window.

Autoscaling use to scales the y-axis according to the maximum and the minimum that occur in all data channels so that the display window displays all peak values. Only use autoscaling to display curve peaks because analyzing input channels and the resulting new scaling requires computer power.

3.2.2 STEP 2 : ANALYSIS USING FAST FOURIER TRANSFORM (FFT)

For the first analysis, Fast Fourier Transform (FFT) in DASYlab is used to analysed the strain and vibration signals. From the FFT, the value of the natural frequency for the experimental value can be find. This value is important as it is use to show the resonance that occur in the system which lead to mechanical failure when it is equal to the excitation frequency of the system.

The first step used is preparing the module as shown in Figure 3.2.2(a). In order to read the data from the experiment, read module is used in this analysis.

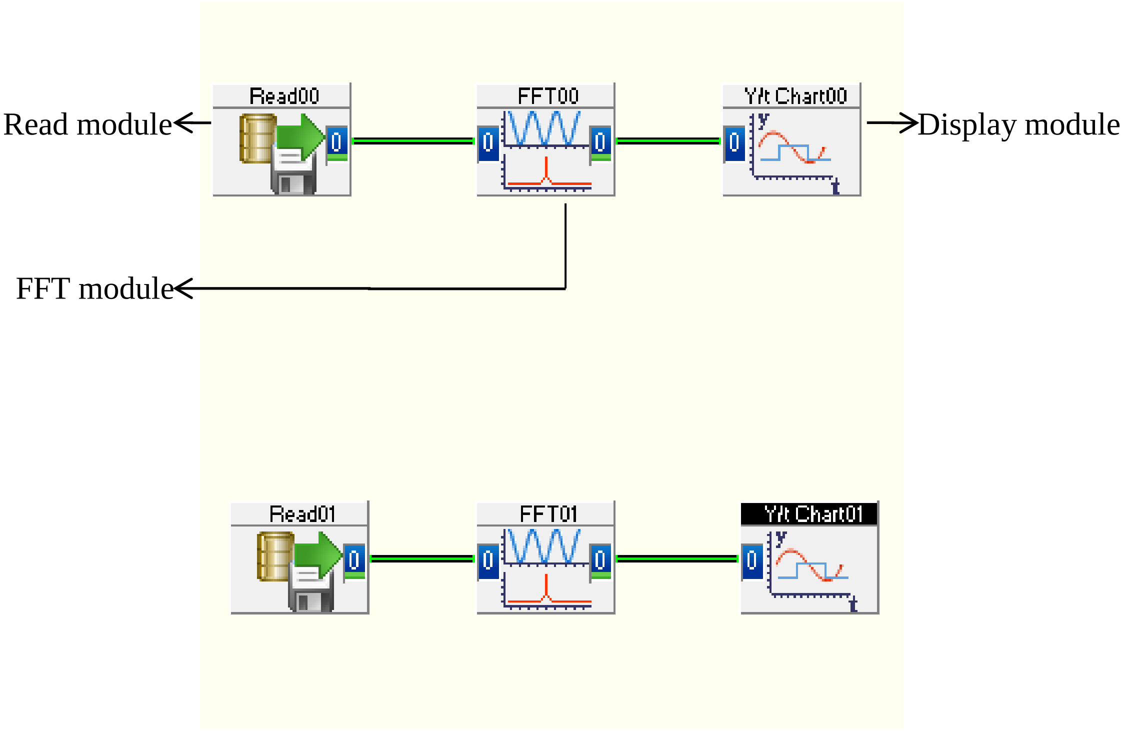


Figure 3.2.2(a) Module setup in Dasylab for FFT analysis

The module that being use for the analysis and its explanation as follow:

Read Data Module

Read data module is used to read data channels and header information from files. The read data module does not have a channel bar, because the structure of the data file to be read determines the number of data channels. The module can read up to 16 data channels and output the data channels to the worksheet.

DASYLab can read the file formats ASCII, DASYLab, Flex4, and IEEE-32-Bit. For this experiment, the read file format is ASCII.FFT Module: Real FFT of a Real Signal (module 2)

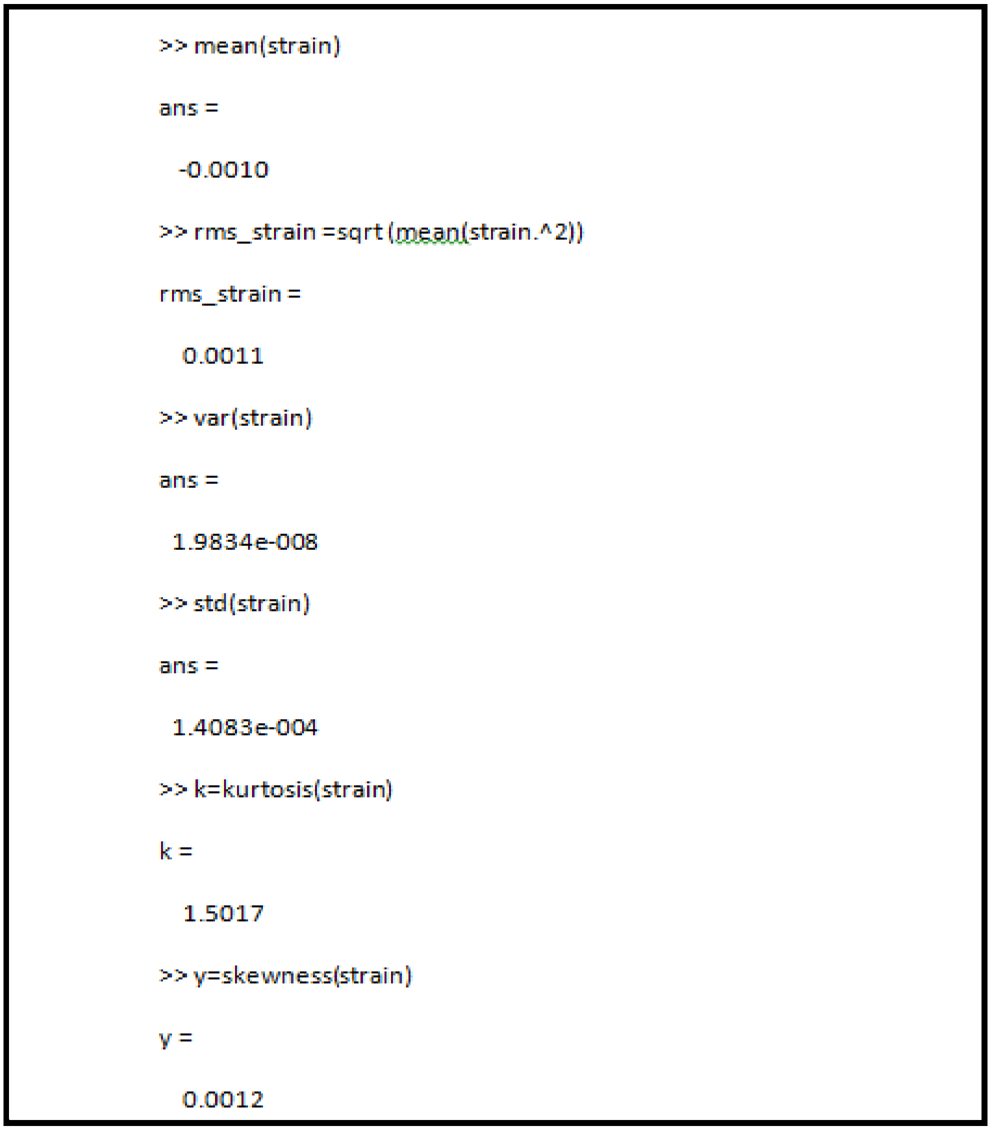
Real FFT of a real signal module is used to transfer up to 16 data channel pairs from the time domain into the frequency domain. dB evaluation can be to make small spectral parts visible. The function of fourier analysis is to calculates the amount of a two-sided fourier spectrum. The output block size is the same as the input block size.

3.2.3 STEP 3 : ANALYSIS USING STATISTICAL METHOD

Statistics is the study of the collection, organization, analysis, interpretation, and presentation of data. It deals with all aspects of this, including the planning of data collection in terms of the design of surveys and experiments.

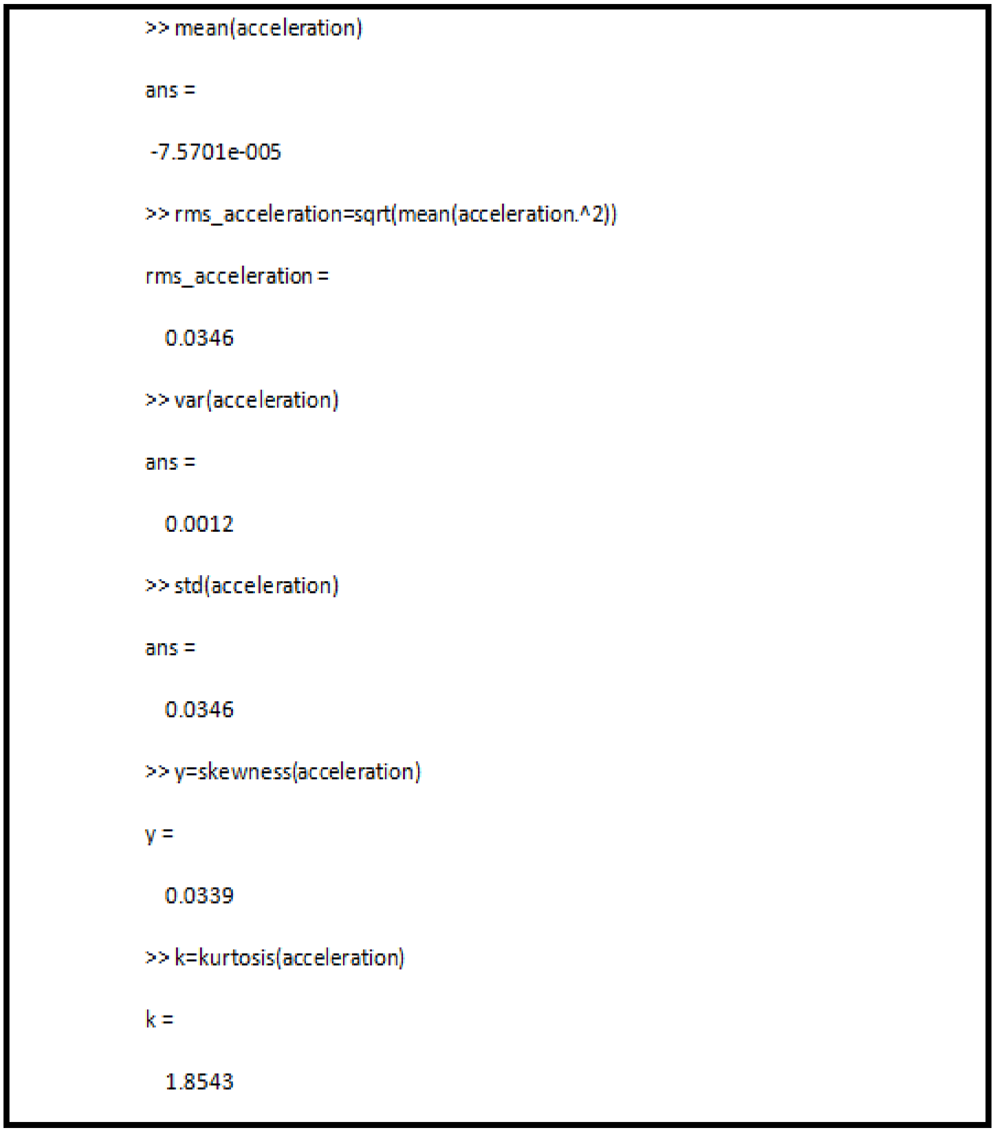
The Statistical analysis which are used in this research are mean, standard deviation, variance, root mean square (r.m.s) , skewness and kurtosis. The software used to get each statistical parameter value is Matrix Laboratory (Matlab).

There are a few steps need to be follow in the Matlab such as the input data of strain and vibration signals and the simple coding for each parameter as shown in Figure 3.2.3(a) for strain and Figure 3.2.3(b) for acceleration**.**



```
>> mean(strain)

ans =

  -0.0010

>> rms_strain =sqrt (mean(strain.^2))

rms_strain =

   0.0011

>> var(strain)

ans =

  1.9834e-008

>> std(strain)

ans =

  1.4083e-004

>> k=kurtosis(strain)

k =

   1.5017

>> y=skewness(strain)

y =

   0.0012
```

Figure 3.2.3(a) Example coding in Matlab for strain at 40Hz



```
>> mean(acceleration)

ans =

 -7.5701e-005

>> rms_acceleration=sqrt(mean(acceleration.^2))

rms_acceleration =

   0.0346

>> var(acceleration)

ans =

   0.0012

>> std(acceleration)

ans =

   0.0346

>> y=skewness(acceleration)

y =

   0.0339

>> k=kurtosis(acceleration)

k =

   1.8543
```

Figure 3.2.3(b) Example coding in Matlab for acceleration at 60Hz

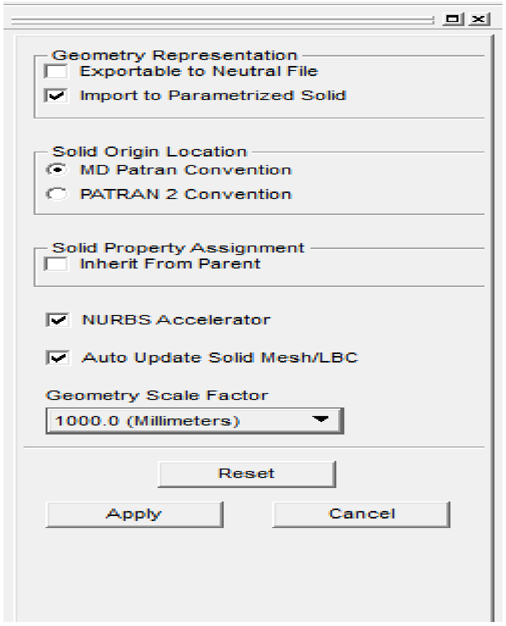
3.2.4 STEP 4 : ANALYSIS USING MARC PATRAN

Marc Patran is used in this research to find the highest strain of the beam and the displacement of the beam and then correlate between both parameter.

There are a few steps involves to get the results from the analysis which stated below.

1. Import file that related to the research which is the beam in parasolid format. Make sure the geometry types is solid and the quantity impoerted is 1.

2. Set the geometry used in milimeters. Preferences > Geometry > Geometry scale factor > 1000 milimeters.



Geometry Representation
☐ Exportable to Neutral File
☑ Import to Parametrized Solid

Solid Origin Location
● MD Patran Convention
○ PATRAN 2 Convention

Solid Property Assignment
☐ Inherit From Parent

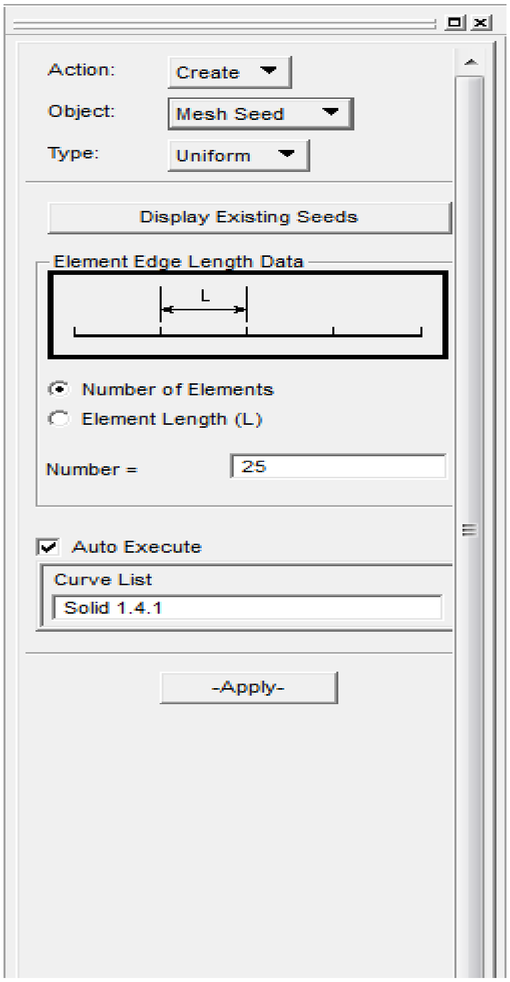
☑ NURBS Accelerator

☑ Auto Update Solid Mesh/LBC

Geometry Scale Factor
1000.0 (Millimeters)

Figure 3.2.4 (a) Setting of the scale factor

3. Set the element as shown in Figure 3.2.4(b) for meshing then removes the nodes that excluded by doing the equivalence as shown in Figure 3.2.4 (c). The beam after the meshing included in Appendix C.



Action: Create

Object: Mesh Seed

Type: Uniform

Element Edge Length Data

● Number of Elements

○ Element Length (L)

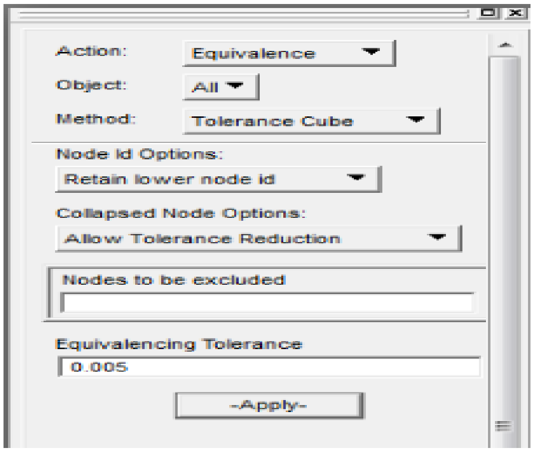
Number = 25

☑ Auto Execute

Curve List

Solid 1.4.1

Figure 3.2.4 (b) Setting of the element



Action: Equivalence

Object: All

Method: Tolerance Cube

Node Id Options:
Retain lower node id

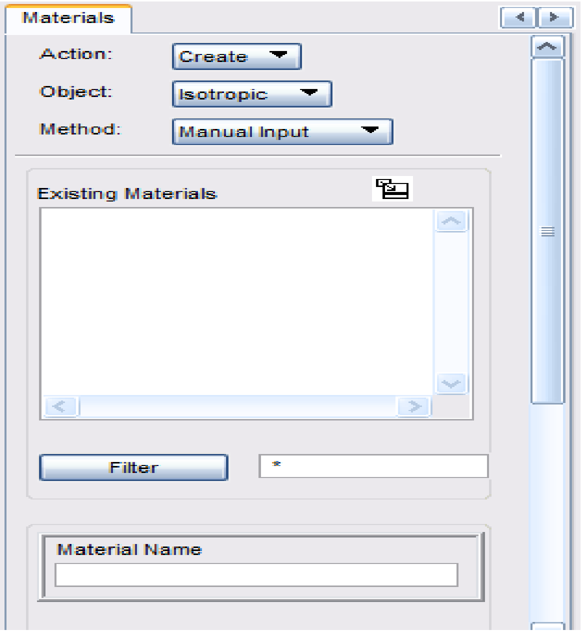
Collapsed Node Options:
Allow Tolerance Reduction

Nodes to be excluded

Equivalencing Tolerance
0.005

Figure 3.2.4 (c) Removing excluded nodes

4. Set the material used in the analysis as shown in Figure 3.2.4 (d) and the input properties as included in Figure 3.2.4 (e)



Action: Create

Object: Isotropic

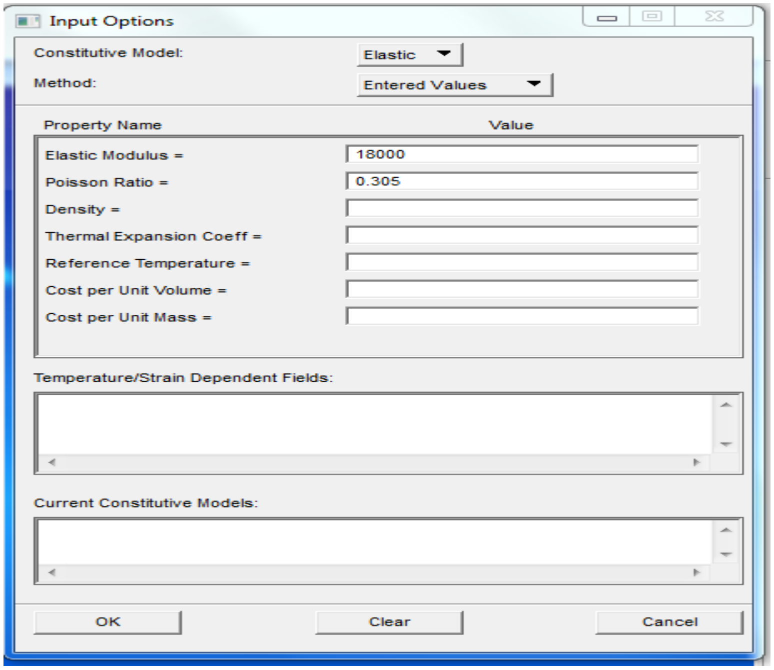
Method: Manual Input

Existing Materials

*

Material Name

Figure 3.2.4 (d) Material setup for beam



Constitutive Model: Elastic

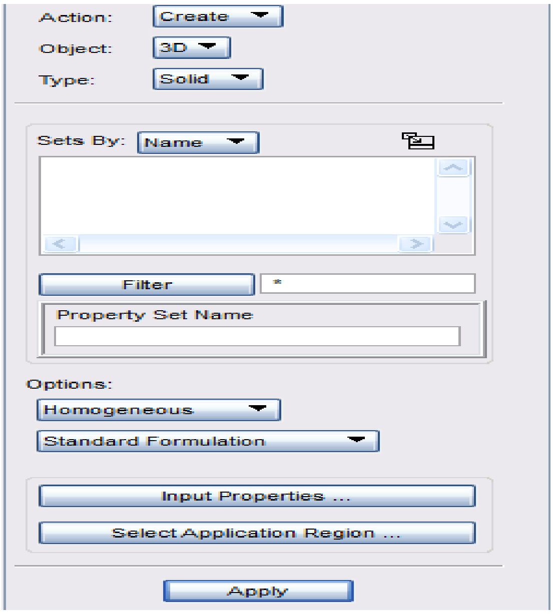
Method: Entered Values

Elastic Modulus = 18000

Poisson Ratio = 0.305

Figure 3.2.4 (e) The input properties of material

5. Properties of the beam is set as 3D solid as shown in Figure 3.2.4 (f).



Action: Create

Object: 3D

Type: Solid

Sets By: Name

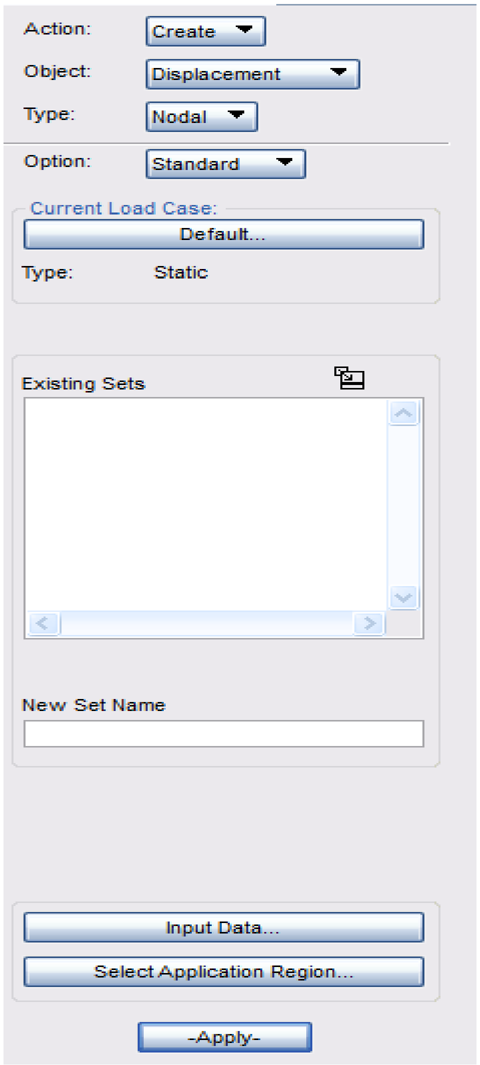
Filter: *

Options: Homogeneous

Standard Formulation

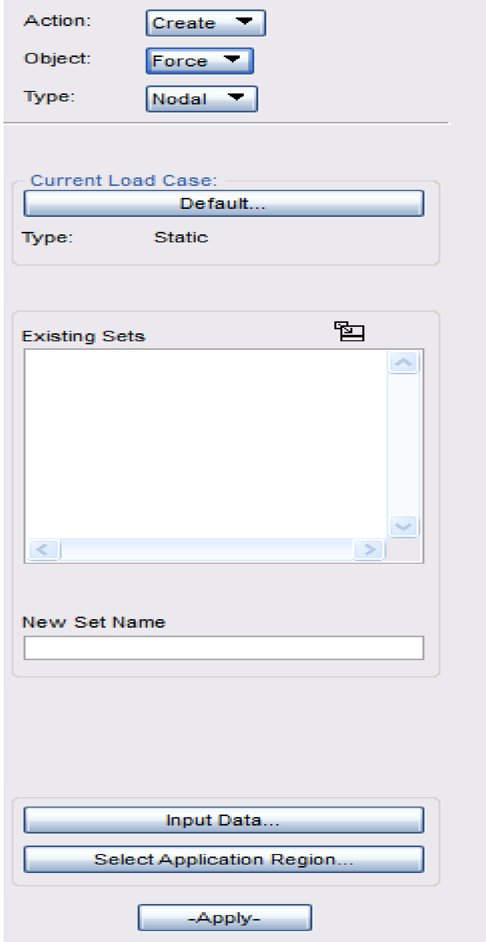
Figure 3.2.4 (f) Properties of beam

6. Setup the load boundary condition for displacement and the force of the beam. Figure 3.2.4 (g) shows the displacement setup while Figure 3.2.4(h) shows force setup.



Action: Create
Object: Displacement
Type: Nodal
Option: Standard
Current Load Case: Default...
Type: Static

Figure 3.2.4 (g) The displacement setup

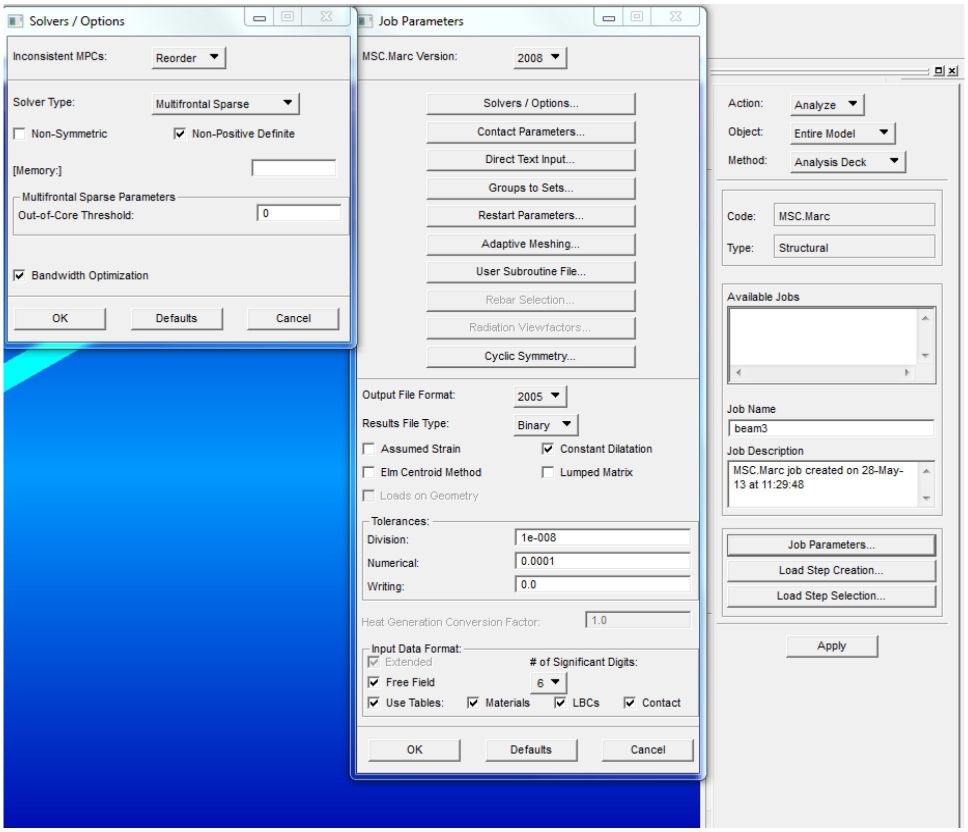


Action: Create
Object: Force
Type: Nodal

Current Load Case: Default...
Type: Static

Figure 3.2.4(h) force setup.

7. Analysis part is done as shown in Figure 3.2.4 (i). The setting for the analysis are the parameter and the solver.



Inconsistent MPCs: Reorder

Solver Type: Multifrontal Sparse

☐ Non-Symmetric ☑ Non-Positive Definite

[Memory:]

Multifrontal Sparse Parameters

Out-of-Core Threshold: 0

☑ Bandwidth Optimization

MSC.Marc Version: 2008

Output File Format: 2005

Results File Type: Binary

☐ Assumed Strain ☑ Constant Dilatation

☐ Elm Centroid Method ☐ Lumped Matrix

☐ Loads on Geometry

Tolerances:

Division: 1e-008

Numerical: 0.0001

Writing: 0.0

Heat Generation Conversion Factor: 1.0

Input Data Format:

☑ Extended # of Significant Digits: 6

☑ Free Field

☑ Use Tables: ☑ Materials ☑ LBCs ☑ Contact

Action: Analyze

Object: Entire Model

Method: Analysis Deck

Code: MSC.Marc

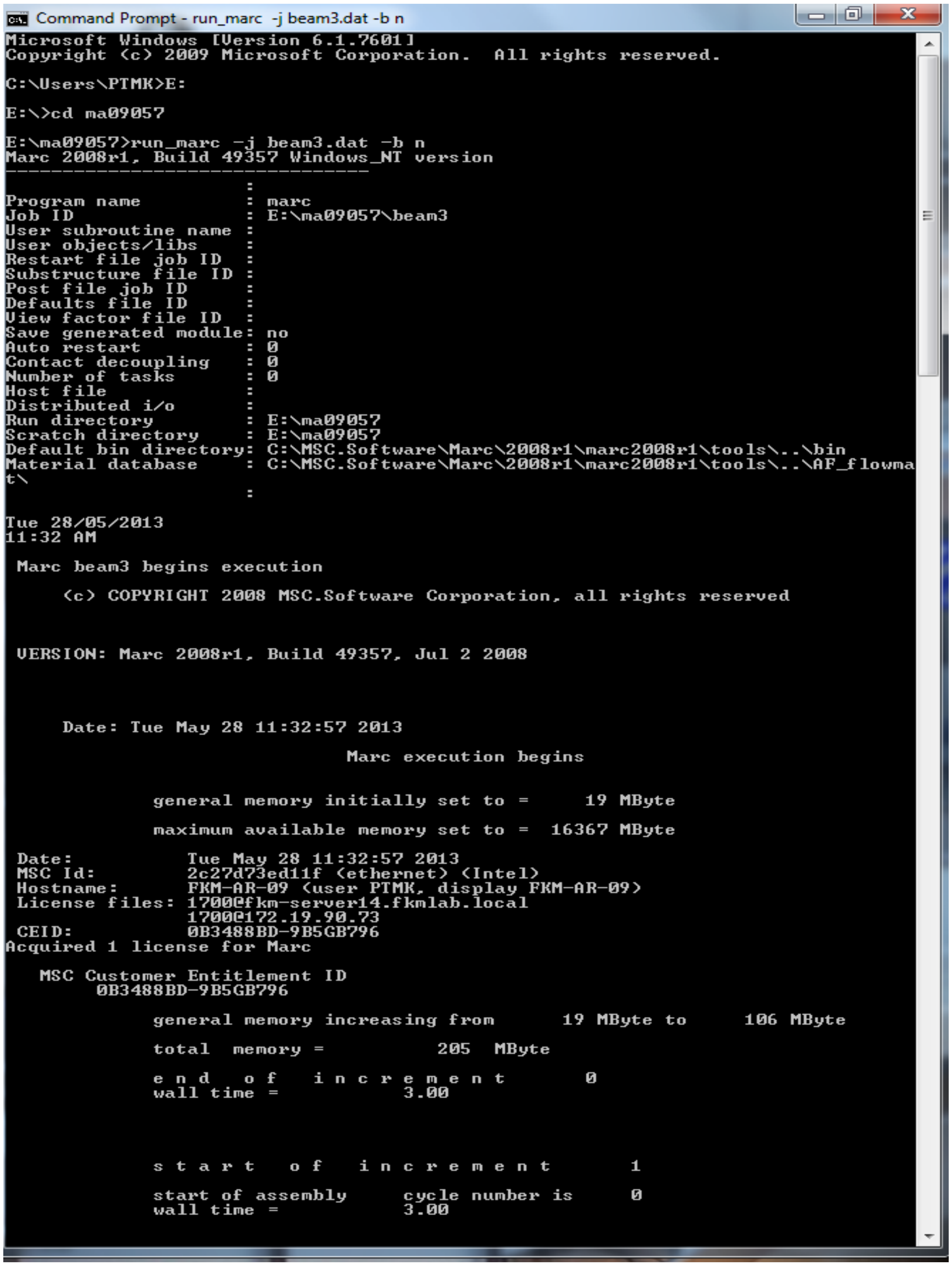
Type: Structural

Job Name: beam3

Job Description: MSC.Marc job created on 28-May-13 at 11:29:48

Figure 3.2.4 (i) Analysis of the beam

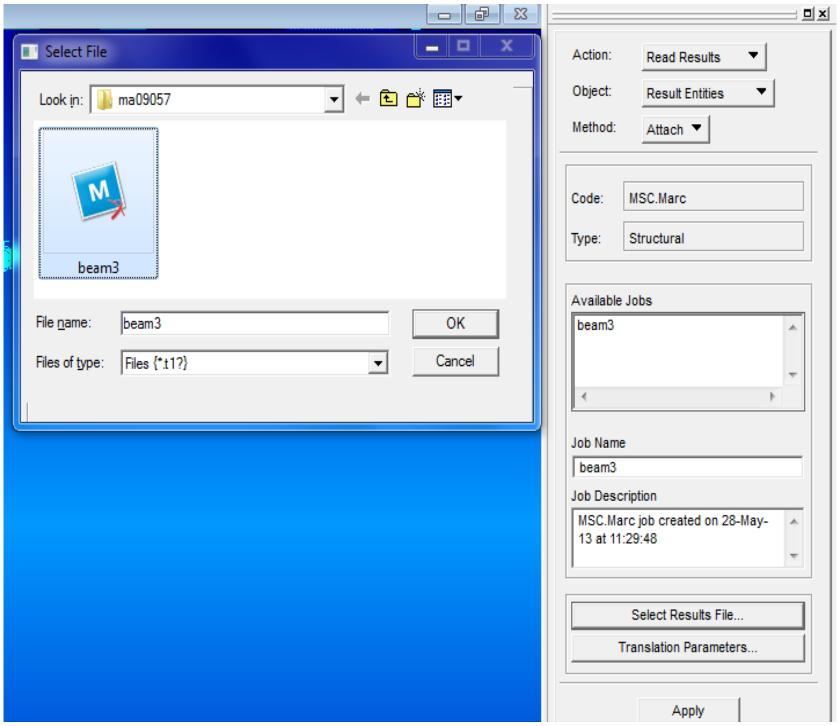
8. Run Marc using the command as shown in Figure 3.2.4 (j). The command is used to run the analysis.



```
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\PTMK>E:

E:\>cd ma09057

E:\ma09057>run_marc -j beam3.dat -b n
Marc 2008r1, Build 49357 Windows_NT version
--------------------------------
                     :
Program name         : marc
Job ID               : E:\ma09057\beam3
User subroutine name :
User objects/libs    :
Restart file job ID  :
Substructure file ID :
Post file job ID     :
Defaults file ID     :
View factor file ID  :
Save generated module: no
Auto restart         : 0
Contact decoupling   : 0
Number of tasks      : 0
Host file            :
Distributed i/o      :
Run directory        : E:\ma09057
Scratch directory    : E:\ma09057
Default bin directory: C:\MSC.Software\Marc\2008r1\marc2008r1\tools\..\bin
Material database    : C:\MSC.Software\Marc\2008r1\marc2008r1\tools\..\AF_flowma
t\
                     :

Tue 28/05/2013
11:32 AM

 Marc beam3 begins execution

     (c) COPYRIGHT 2008 MSC.Software Corporation, all rights reserved


 VERSION: Marc 2008r1, Build 49357, Jul 2 2008



     Date: Tue May 28 11:32:57 2013
                              Marc execution begins

             general memory initially set to =     19 MByte

             maximum available memory set to =  16367 MByte

 Date:          Tue May 28 11:32:57 2013
 MSC Id:        2c27d73ed11f (ethernet) (Intel)
 Hostname:      FKM-AR-09 (user PTMK, display FKM-AR-09)
 License files: 1700@fkm-server14.fkmlab.local
                1700@172.19.90.73
 CEID:          0B3488BD-9B5GB796
Acquired 1 license for Marc

   MSC Customer Entitlement ID
        0B3488BD-9B5GB796

             general memory increasing from      19 MByte to      106 MByte

             total  memory =          205  MByte

             e n d   o f   i n c r e m e n t       0
             wall time =           3.00



             s t a r t   o f   i n c r e m e n t       1

             start of assembly     cycle number is     0
             wall time =           3.00
```

Figure 3.2.4 (j) Command for Marc

9. Accessed the result after done with the command as shown in Figure 3.2.4(k).



Look in: ma09057
File name: beam3
Files of type: Files (*.t1?)
Action: Read Results
Object: Result Entities
Method: Attach
Code: MSC.Marc
Type: Structural
Available Jobs: beam3
Job Name: beam3
Job Description: MSC.Marc job created on 28-May-13 at 11:29:48

Figure 3.2.4(k). Step to access result

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter describes and discusses the results obtained from each of steps in methodology. The result obtained described by graph to correlate both signals.

4.2 STATISTICAL DATA

The data are collected in different frequency which are 10 Hz, 20 Hz, 30 Hz, 40 Hz, 50 Hz and 60 Hz. The experimental data are analysed according to statistical parameter and the result as shown in Table 4.2 (a) for strain signals and Table 4.2(b) for vibration signals.

Table 4.2 (a) Strain signals

Frequency (Hz)	Mean	Root Mean Square (RMS)	Variance	Standard Deviation	Skewness	Kurtosis
10	-1.4711E-005	1.00E-03	-1.1847E-005	6.21E-06	-0.0471	3.0266
20	-0.0010	0.001	4.3391E-011	6.59E-06	0.3163	2.083
30	-0.0010	0.001	4.7532E-010	2.18E-05	-0.0181	1.7267
40	-0.0010	0.0011	1.9834E-008	1.01E-04	0.0012	1.613
50	-0.0010	0.001	3.6073E-009	6.01E-05	-0.0073	1.5038
60	-0.0010	0.001	1.4129E-009	3.76E-05	-0.0192	1.5014

Table 4.2(b) Vibration signal

Frequency (Hz)	Mean	Root Mean Square (RMS)	Variance	Standard Deviation	Skewness	Kurtosis
10	-1.4711E-005	0.0034	1.1847E-005	0.0034	-0.0471	3.0266
20	-2.2567E-005	0.0055	3.0717E-005	0.0055	-0.0744	2.4592
30	-8.5355E-007	0.0081	6.6134E-005	0.0081	0.1594	1.968
40	-1.6923E-004	0.0564	0.0032	0.0564	0.0420	1.8063
50	-7.6654E-005	0.038	0.0014	0.0380	-0.0336	1.7385
60	-7.5701E-005	0.0346	0.0012	0.0346	0.0339	1.8543

4.2.1 Statistical Data Analysis

From the collected data, the statistical value of both signals is correlate using graph . In order to achieve the objective of this research, the main parameter of statistical data which show positively correlation between these two signals are standard deviation and the kurtosis.

Figure 4.2.1(a) show the correlation between the standard deviation of strain signal and the standard deviation of vibration signal while Figure 4.2.1 (b) show the correlation of kurtosis for both signal. All of the statistical graph choose shows that the strain signal and vibration signal are linearly related.

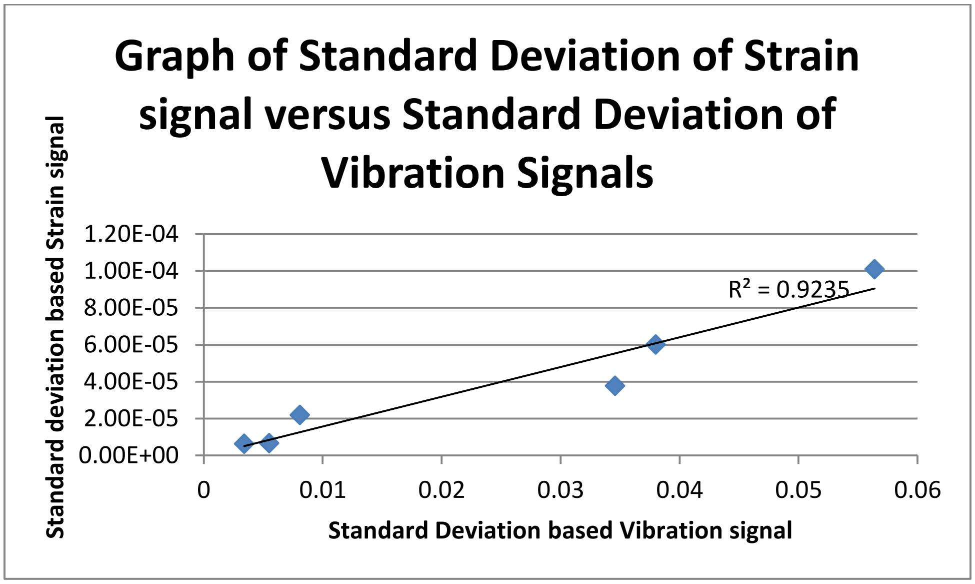


Figure 4.2.1(a) Graph of Standard Deviation based on strain signal versus Standard Deviation based on Vibration signal

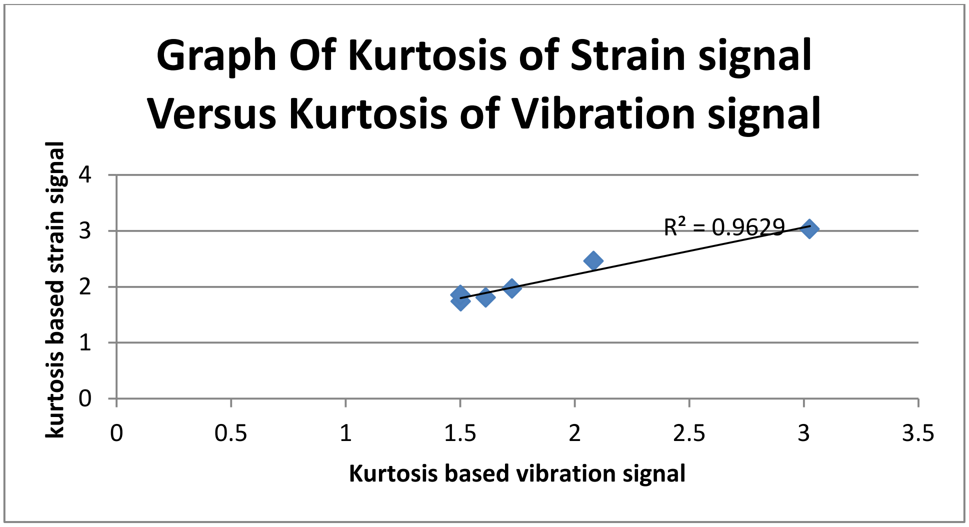


Figure 4.2.1(b) Graph of Kurtosis based on strain signal versus Kurtosis based on Vibration signal

4.3 FAST FOURIER TRANSFORM RESULTS

Figure 4.3(a) show the Y/t chart of the strain signal after FFT at 10Hz and the Y/t chart for other frequency are included in Appendix A . The Y/t chart show the amplitude of the strain signal during the experiment.

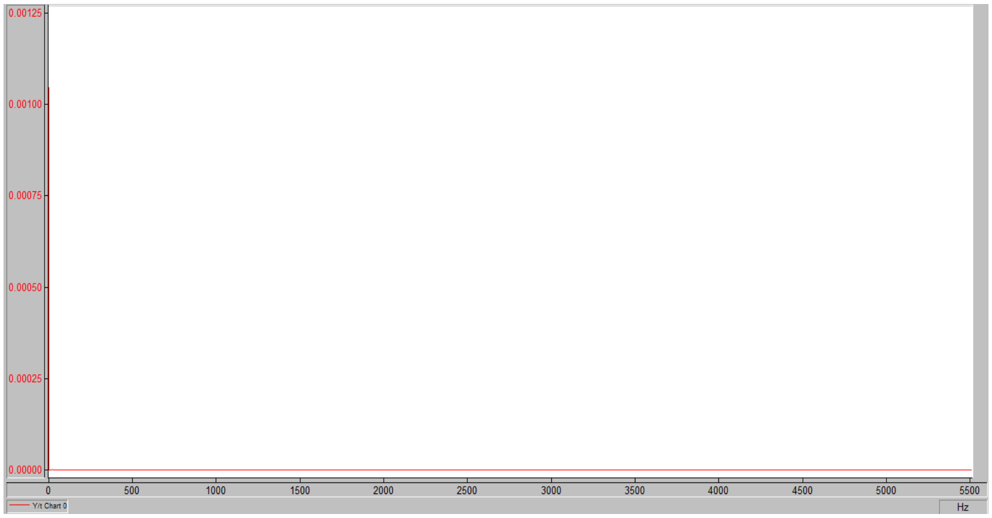


Figure 4.3(a) Y/t chart of Strain Signal after FFT at 10 Hz

Figure 4.3(a) show the Y/t chart of the vibration signal after FFT at 10Hz and the Y/t chart for other frequency are included in Appendix B . The Y/t chart show the amplitude of the vibration signal during the experiment.

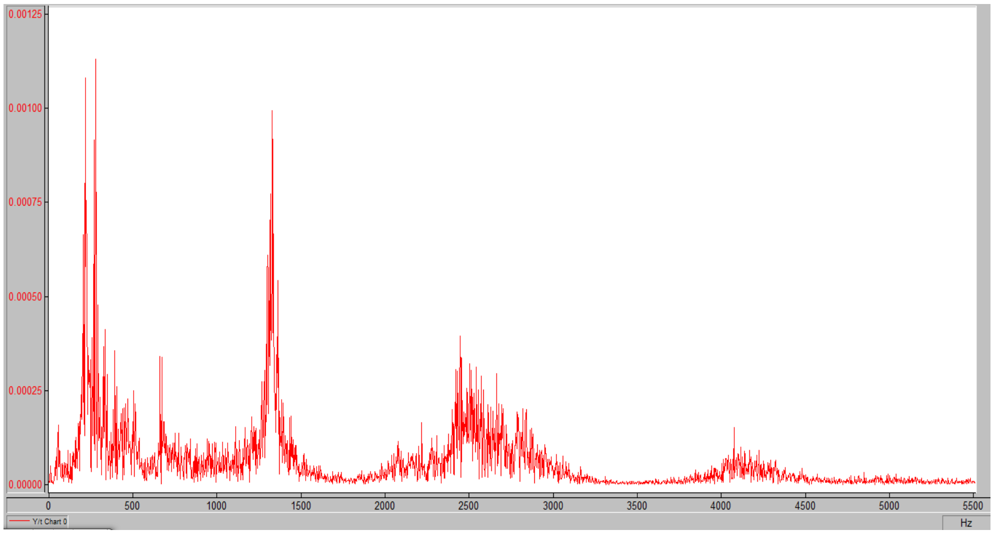


Figure 4.3(b) Y/t chart of Vibration Signal after FFT at 10 Hz

4.3.1 Amplitude from FFT

Table 4.3.1 shows the amplitude of strain signal and vibration signal after FFT.

Table 4.3.1 The amplitude of strain signal and vibration signal after FFT

Frequency	Amplitude	
	Strain signal	Vibration signal
0.1667	0.00000833	0.00163
0.3333	0.0000167	0.00164
0.5	0.0000333	0.00612
0.6667	0.000158	0.07012
0.8333	0.0000867	0.05088
1.0	0.0000708	0.04647

The correlation between amplitude of the strain signal and the vibration signal is shown in the Figure 4.3.1. The amplitude show that both signal has linearly proportional correlated. When the vibration increase, the strain also increase.

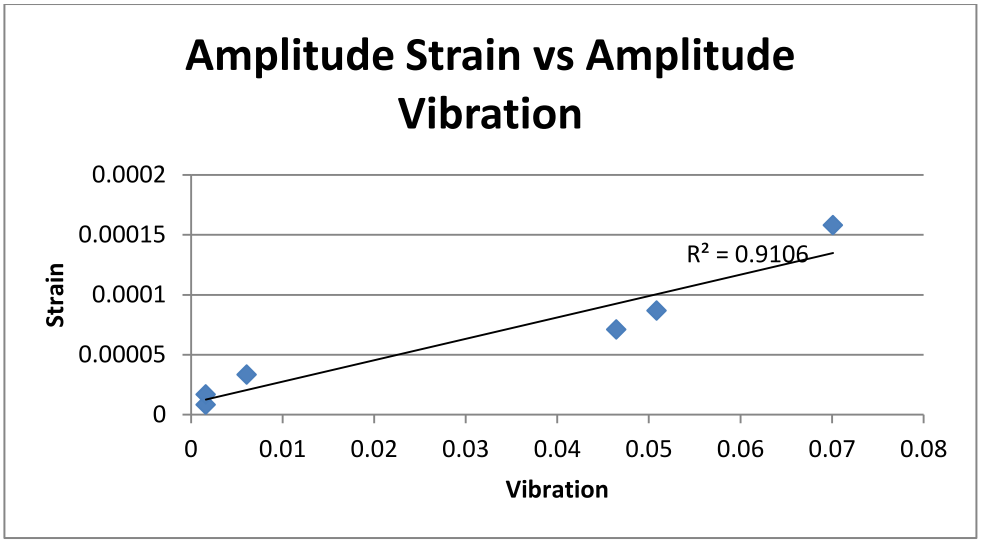


Figure 4.3.1 The amplitude of strain signal versus amplitude of vibration signal

4.4 DEFORMATION ANALYSIS

Deformation analysis is done using Marc Patran software which show the distribution of the strain and displacement part on a beam. The distribution is shown in Figure 4.4.1.

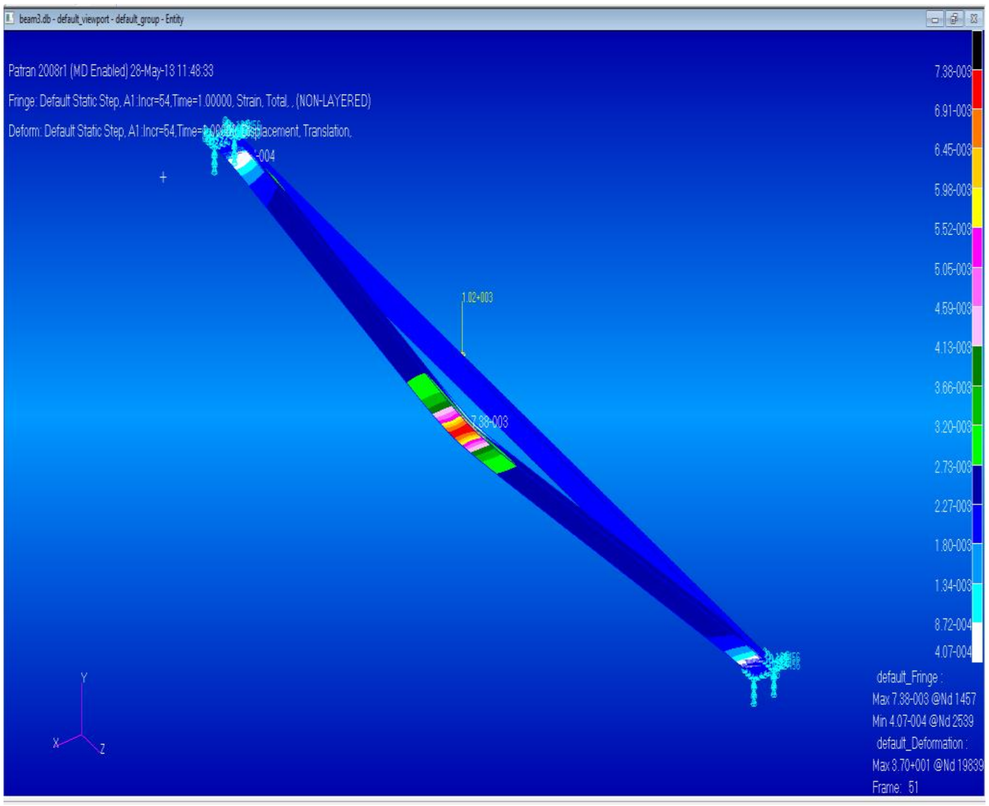


Figure 4.4.1 Distribution of the strain and displacement on a beam

Table 4.4 show the value of the strain and the displacement that act on the beam based on the reaction of the force to the beam. The value of both strain versus displacement value are plotted on a Figure 4.4.2. The figure shows that the strain value is linearly related to the displacement.

Table 4.4 The reading of strain value and displacement value after applied force.

Length	Reading	
	Strain	Displacement
0	0.005258	6.39E-02
50	0.006384	0.093311
100	0.007281	0.092939
150	0.00752	0.104157
200	0.007644	0.10502
250	0.007816	0.108525
300	0.008521	0.178518
350	0.008745	0.228364
400	0.008956	0.315718
450	0.009786	0.458115
500	0.010972	0.589267
550	0.009875	0.483667
600	0.009026	0.41156
650	0.008888	0.356688
700	0.008754	0.271145
750	0.008726	0.149496
800	0.008625	0.097978
850	0.007825	0.093331
900	0.00724	0.092433
950	0.006421	0.092879
10000	0.005462	7.58E-02

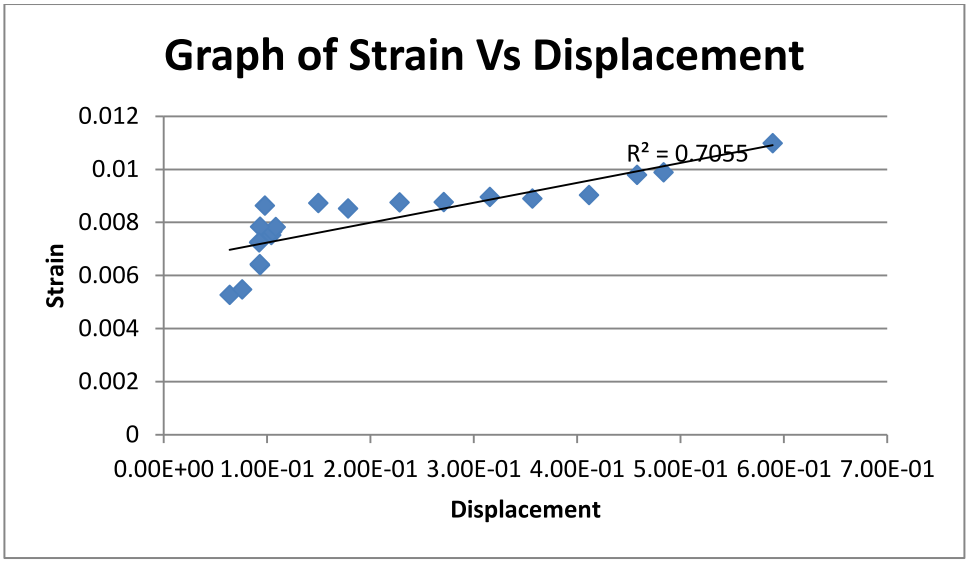


Figure 4.4.2 Graph of Strain versus Displacement of a beam after applied force.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This research is about the comparative study of strain signal and the vibration signal of a beam which were taken by the experiment and the software analysis. From the experiment, the data which were varied from 10 Hz to 60 Hz were analyze using statistical analysis and Fast Fourier Transform (FFT). For the statistical data, the correlation between the signal depends on the kurtosis since the kurtosis is used in engineering for detection of fault symptoms because of its sensitivity to high amplitudes events. A graph of strain amplitudes versus vibration amplitudes from FFT were plotted to show the relationship using FFT. Besides, the analysis from the Marc Patran were used to show the distribution of the strain and the displacement after being forced at 100N and a graph of strain value and the displacement value were plotted. From the statistical data, FFT and Marc Patran analysis, the results shows that the strain signal polynomially related to the vibration signal.

5.2 RECOMMENDATIONS

5.2.1 Fatigue Life Assessment and Modal analysis

There are better way to make correlation by doing the fatigue life assessment from the experiment and use the software such as glyphworks or Ansys to find the fatigue life of the beam. Then, compare the results from the fatigue life with the natural frequency data from the modal analysis which represent the vibration signal.

5.2.2 Considering Mass in Force Vibration Experiment

In order to find the natural frequency of the beam used, varies the mass of the load apply on the beam. This is the alternative way besides using the modal analysis.

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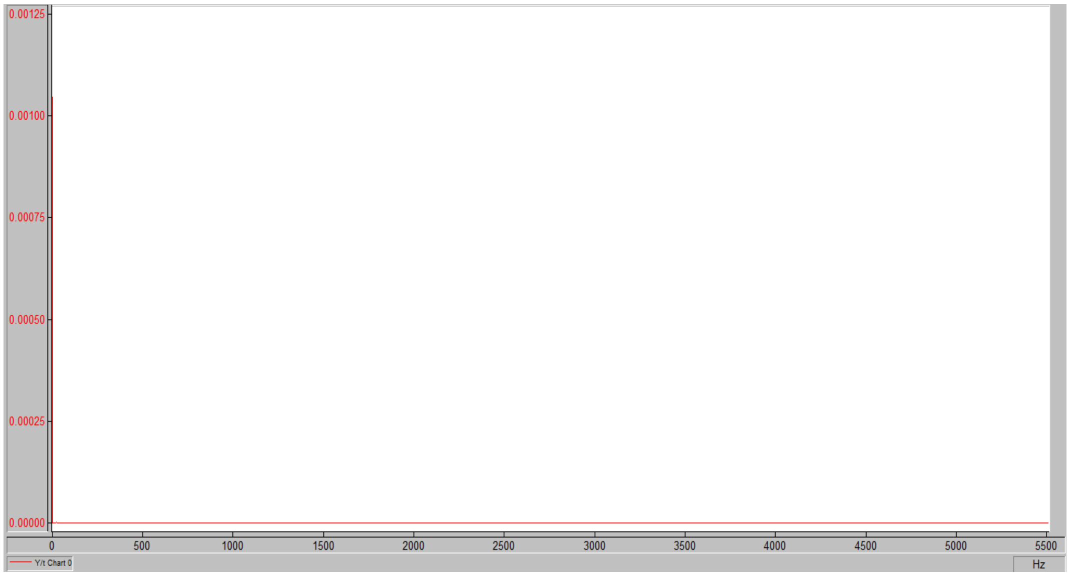
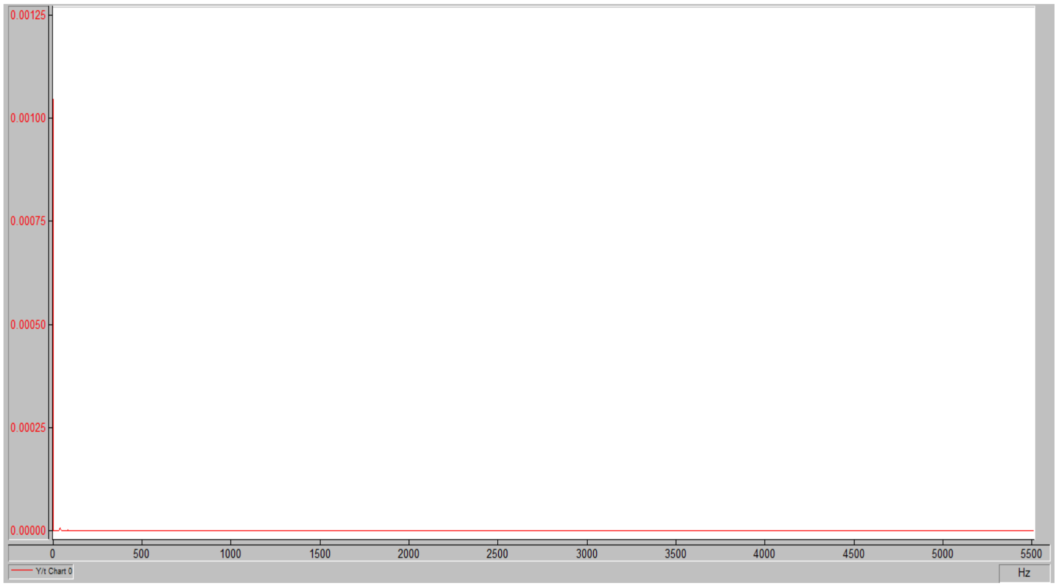
APPENDIX A

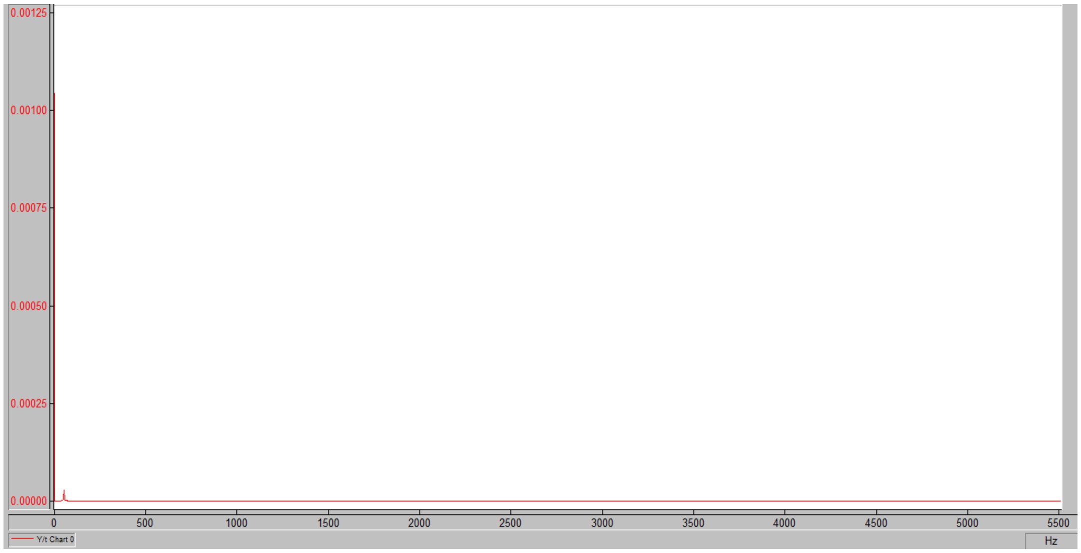
FFT at 10 Hz



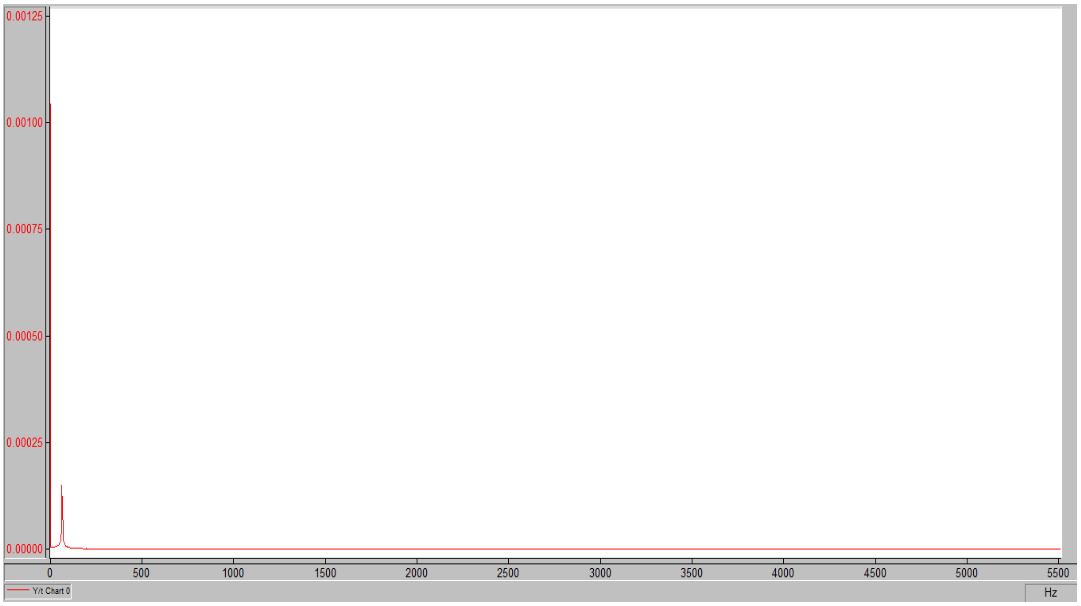
FFT at 20 Hz



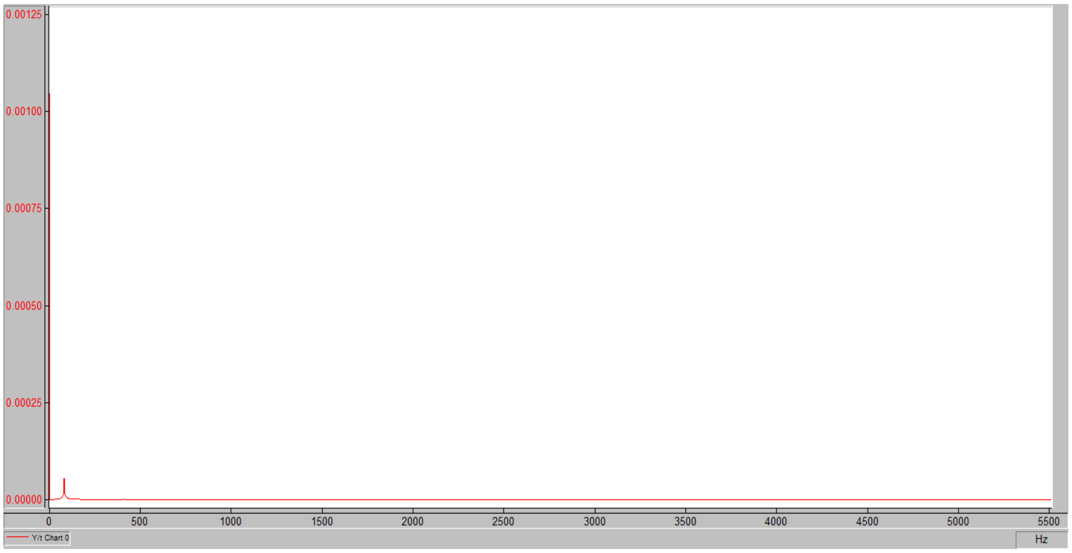
FFT at 30 Hz



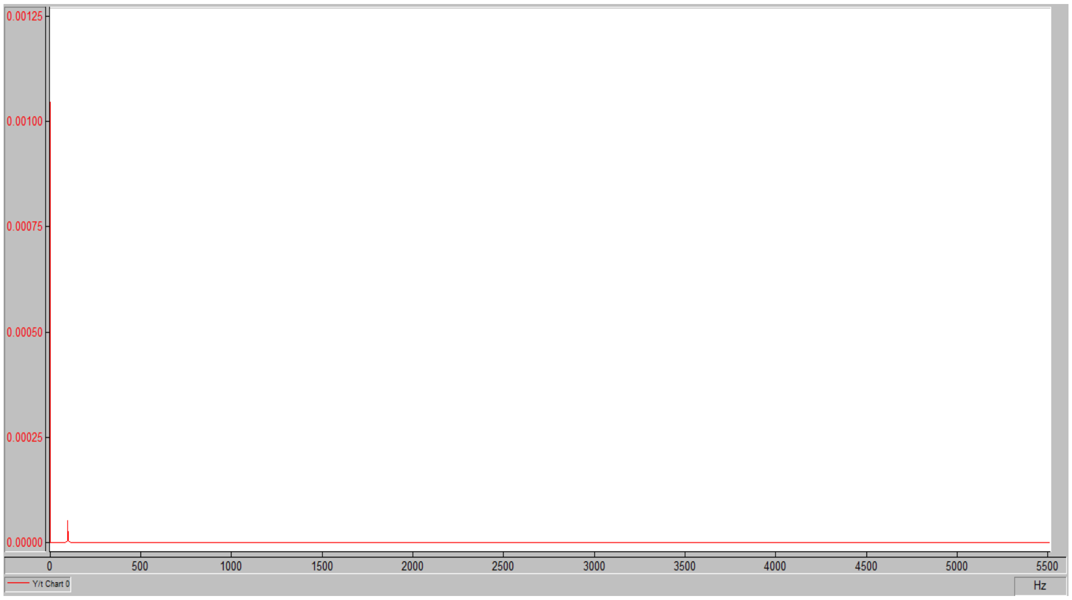
FFT at 40 Hz



FFT at 50 Hz

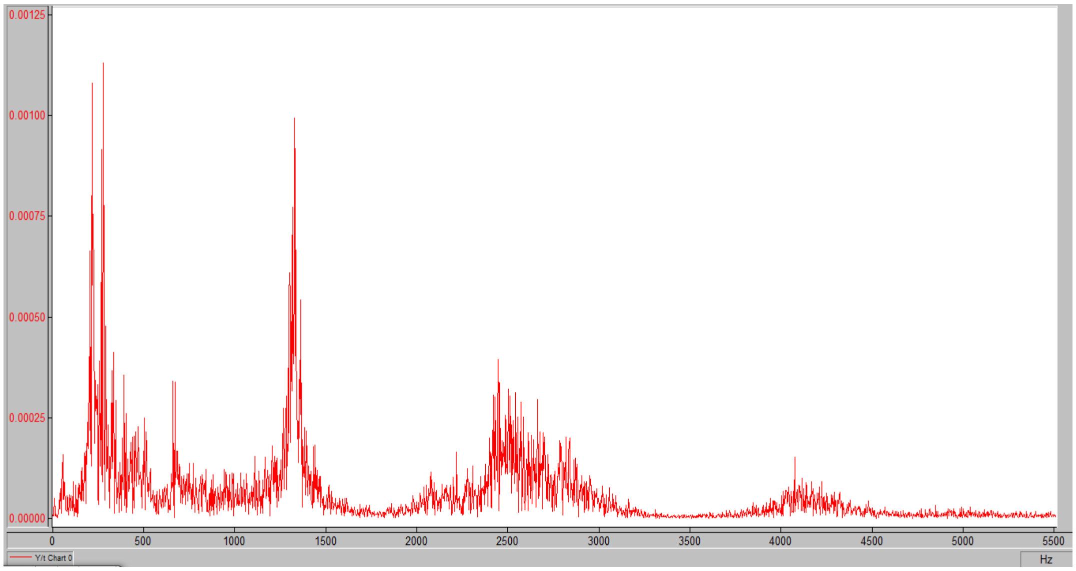


FFT at 60 Hz

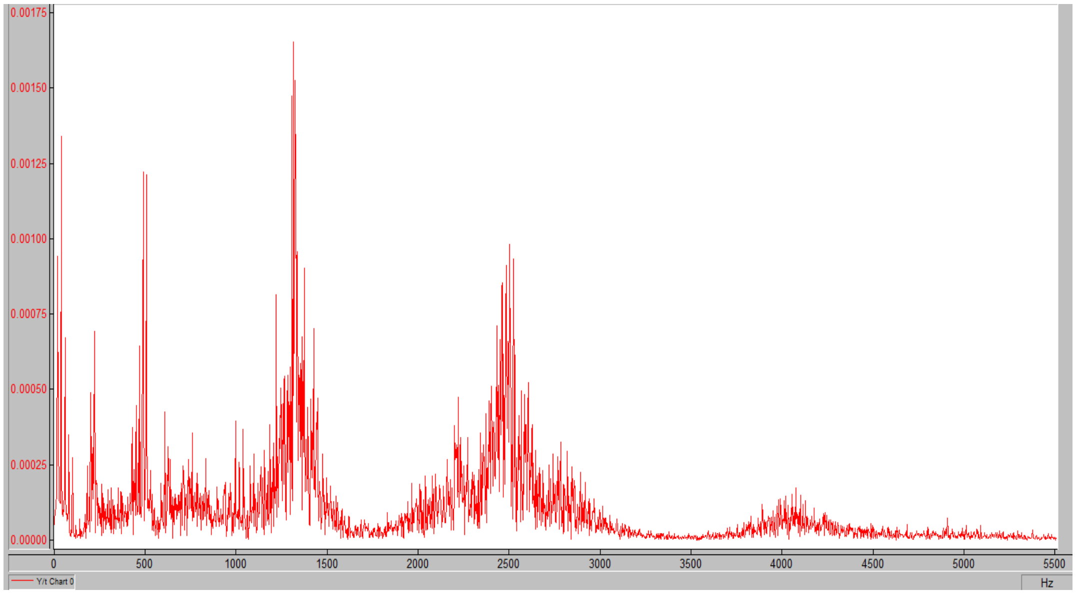


APPENDIX B

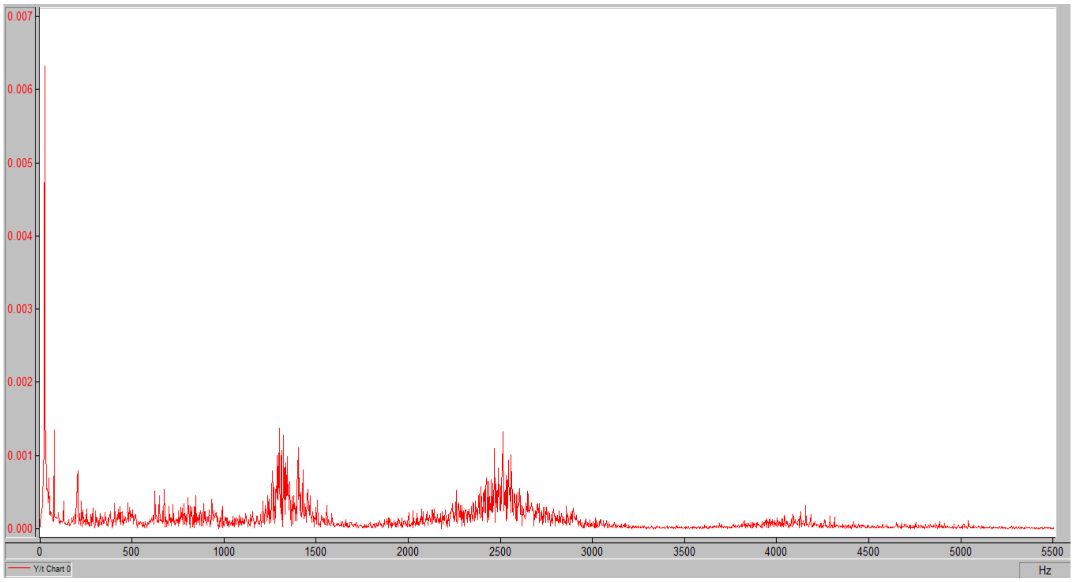
FFT at 10 Hz



FFT at 20 Hz



FFT at 30 Hz



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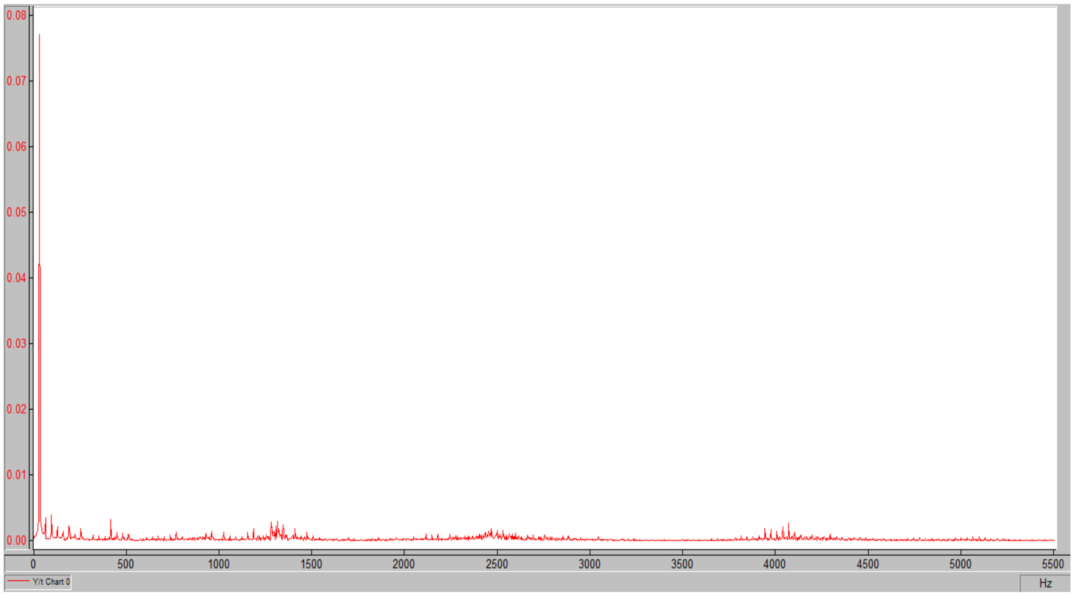
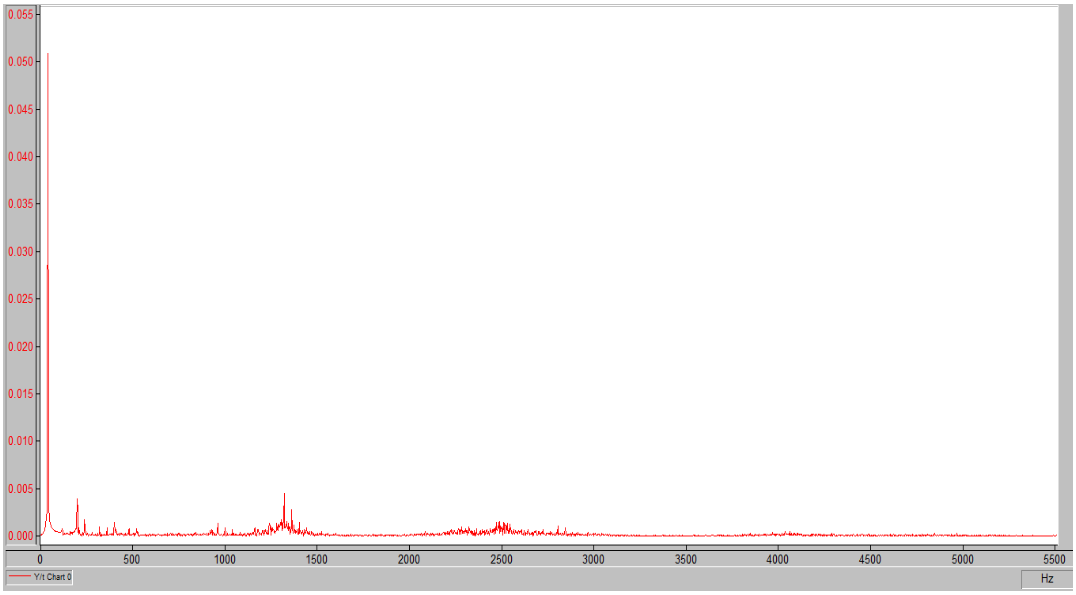


FFT at 50 Hz



FFT at 60 Hz