FATIGUE STRAIN SIGNAL BEHAVIOR OF AUTOMOBILE SUSPENSION SYSTEM

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A report submitted

in fulfilment of the requirements for the

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in term of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure and Material).

Signature :……………………….
Name of supervisor :……………………….
Date :……………………….

DECLARATION

I declare that this project report entitled "Fatigue Strain Signal Behaviour of Automobile Suspension System" is the result of my own work except as cited in the references.

Signature	:…………………………….
Name of Author	: Mohamad Iqmal Faris bin Idris
Date	:

To my beloved family especially my mother, Samirah binti Simoh and my father, Idris bin Kassim

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In the name of Allah, the most Gracious and most Merciful

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ABSTRACT

Generally, spring suspension is one of the important part in automobile components which act to support and holds the body of the automobile from shaking and vibration. Driving become uncomfortable when automobile passes through the high magnitude road such as hills and small magnitude road such as road roughness. Therefore, this project discusses the fatigue life prediction of the spring suspension by obtaining the strain signal behaviour of two different road surface and the static analysis using Ansys workbench software. An investigation and analysis is done by Solidwork drawing, Ansys for static and Design life nCode software for fatigue analysis. The behaviour of strain signals was analysed by using statistical method. The damage and life cycle value of the spring suspension also been obtained by using commercial Design life software. Basically, the fatigue strain signal behaviour significantly influenced by the type of road surfaces which directly affected the damage and life cycle of the spring suspension. After all the information been identify, the fatigue life prediction can be done to evaluate the reliability and suitability of the spring. Perodua Myvi is choose in this project due to higher sales in Malaysia market and the result can be used in the future for further study.

ABSTRAK

Secara umumnya, pegas penggantungan adalah salah satu bahagian yang penting dalam komponen kereta yang bertindak untuk menyokong dan memegang badan kereta dari gegaran dan getaran. Pemanduan menjadi tidak memuaskan apabila kereta dipandu melalui jalan yang berbukit dan kekerasan jalan yang berbeza. Oleh itu, projek ini membincangkan ramalan hayat pegas penggantungan dengan mendapatkan tingkah laku isyarat tekanan daripada dua permukaan jalan yang berbeza dan analisis statik menggunakan perisian Ansys. Penyiasatan dan analisis dilakukan dengan lukisan Solidwork, ANSYS untuk analisis kekal dan ncode untuk menilai jangka hayat pegas setelah tekanan berulang dikenakan.. Kelakuan isyarat tekanan dianalisis dengan menggunakan kaedah statistik. Kerosakan dan kehidupan nilai kitaran pegas penggantungan juga diperolehi dengan menggunakan perisian kehidupan reka bentuk yang komersial digunakan. Pada asasnya, tingkah laku isyarat tekanan yang berulang jelas ketara dipengaruhi oleh jenis permukaan jalan raya yang secara langsung memberi kesan kerosakan dan kehidupan kepada pegas penggantungan. Selepas mengenal pasti semua maklumat, ramalan hayat boleh dilakukan untuk menilai kebolehpercayaan dan kesesuaian pegas penggantunagn. Perodua Myvi dipilih dalam projek ini kerana jualan yang lebih tinggi di pasaran Malaysia dan hasilnya boleh digunakan pada masa akan datang untuk kajian lanjut.

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R.M. S	Root Mean Square

CHAPTER 1

INTRODUCTION

1.0 BACKGROUND

Suspension is one of the most crucial components in a car system. The main function of this suspension system is to protect the passenger and the car from shaking when they drive across the road with bump or hole or even on the smooth road in order to ensure the wheels follow the road profile. Suspension system is creating to provide a good ride and handling performance of the car. It consists of three main part including suspension spring, suspension damper and suspension bushes.

In the present type of car spring, there come in three types which are leaf spring, torsion bar spring and coiled spring. Leaf spring is a layer of metal beams that entwined and it is associated with the axle. The torsion bar all alone is a strange little contraption which gives wound spring-like execution in view of the contorting properties of a steel bar. One end of the steel shaft is associated with the axle and the other side which is opened into a tube and held there by splines. For the coiled spring, it is a steel bar but it is coiled up and the mechanism of pushing it down is similar as twisting the metal bar.

This car part as named shock absorber plays role to dampen the vertical motion when the drive along rough surface. In addition, this part is to make sure the wheels are always planted on the road. If the car only had spring, the passenger will experience the wallow along the road until they got physically sick and hard to get out or the car.

Furthermore, at one stage the suspension system will achieved failure due to the stress and force applied to the component. The type of failure is fatigue. Fatigue is a phenomenon related with variable loading or more precisely to cyclic stressing or straining of a material. Fatigue obviously occur when a specific task is repeatedly performed, in same method metallic components subjected to variable loading get fatigue, which leads to their ultimately failure under specific conditions (Chetan et al. 2012).

According to ASTM fatigue life clearly specify as the number of stress cycles of a specified character that specimens maintain before failure of a specified nature ensue. Suspension system of vehicle can achieve failure due to the cyclic load. Stress-life method, strain life method and linear-elastic fracture mechanics method are the three basic fatigue life method used in design and analysis. Mechanistically, fatigue failure can be pursuing by gradual enlargement of fatigue cracks during the tensile part of the loading cycle. Once a crack reaches a certain critical size, a big failure ensues. The application and behaviour of fatigue crack growth is fully effected by the formation of characteristic striation patterns on the fracture surface called beach markings. In another point of view, fatigue failure is associated with distinctive dislocation network arrangements, which result from the cyclical nature of loading (Chetan et al., 2012).

Thus, fatigue study and life prediction on the suspension system is necessary in order to verify the safety of this suspension system during its operation. Nowadays, many researchers in the automobile industry have taken the opportunity to improve the design of suspension system.

This study examines and to predict the fatigue life of suspension system by analyse the characteristic of three different road profiles using statistical method. This investigation will be done by attached the strain gauge to a suspension system that will be connected to data acquisition in order to obtain the signals. At the end of this research, the fatigue life of suspension system will be predicted.

1.1 PROBLEM STATEMENT

The issue that always be raised is the driving become uncomfortable when passes through the high magnitude road such as hills and small magnitude road such as road roughness. In other word, it influences by road disturbance. Next, load disturbance also one of the role which the variation of the load induced such as when accelerating, braking and cornering. In addition, the suspension sometime is less in performance due to the contact of tyre with road. The suspension of automobile achieves the failure in a short time in certain condition and this must be preventing correctly.

1.2 OBJECTIVE

1) To obtain the fatigue strain signal of spring suspension when driven into different road surface.
2) To determine fatigue strain signal characteristic using statistical method.
3) To predict the fatigue life of automobile spring suspension system.

1.3 SCOPE OF PROJECT

The first element need to be considered is to do the finite element analysis using software analysis. Analysis enables to get the static analysis and stress analysis to be done on the suspension. Static analysis formed in terms of load of the car, model CAD and constrains.

The second element is conducting the experiment to get the data. The strain gauge is placed at the suspension of the car to verify the signal. Then the data collected from strain gauge proceed with statistical analysis.

The third element is fatigue life analysis that runs by using Design Life software. The result of static analysis from analysis software imported to this stage. The data signal from strain gauge also is imported to run this software. Design Life software is an engineering test data analysis with specific application for fatigue analysis.

Lastly, the process requires analysis of the signal classification based on the value of the statistical analysis result. Behaviour of the strain signals at different type of road is determined and fatigue life prediction is made.

CHAPTER 2

LITERITURE REVIEW

2.1 AUTOMOBILE SUSPENSION SYSTEM

Car suspension systems play a major role in car performance. The performance of the car is not necessarily depending on the engine system. Every vehicle moving on the randomly profiled road is exposed to vibrations which are hazardous to the passengers in terms of comfort and for the sustainability of the vehicle itself. Many aspects need to be consider in order to get the best performance of the car and suspension is one of the aspects. In general, a good suspension should provide a comfortable ride and good handling (Lavanya, et al., 2014). Besides that, all of this is directly depending on the purpose of the vehicle. Sports cars normally have stiff, hard suspensions with poor ride quality while luxury sedans have softer suspensions but with bad road handling capabilities but the aim clearly same which is to reduce all the disturbances. A fundamental suspension system includes of the parts springs, axles, shock absorbers, arms rods and ball joints as shown on Figure 2.1. The main purpose of the suspension is to ensure the tires in contact with the road smoothly, regardless of road surface.

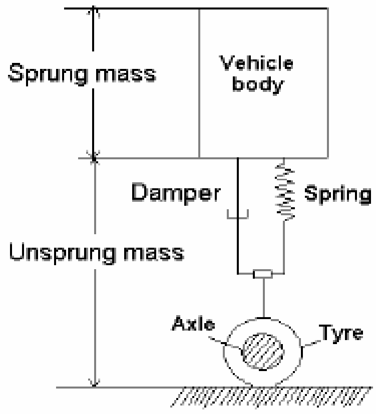


Figure 2.1: Free body diagram of quarter car model

(Jadhav et all., 2014)

2.2 HELICAL SPRING OF SUSPENSION

Helical spring is one of the parts on suspension system with embedded to maintain the capability of the suspension. Based on the Puff (2010), the helical spring had been applied to Reciprocating Compressors with significant importance to control the noise and vibration of the compressor. Springs are basically used in mechanical part as a main function to absorb the load from moving part, which may be continuously, or abrupt difference. Elastic energy is being form in order to absorb the loads. Energy is stored in the spring until the force is released end up at one point the spring will return to the original shape when force is released.

In addition, a helical spring comes with variety of shape which is cylindrical, conical, tapered, concave or convex. But the most frequent type of spring been used in automobile industry is coil spring although there are many other types provided and quite depend on the vehicle suspension system. The cylindrical shape had been choosing in this study due to the present usage in car industry as shown on Figure 2.2

Figure 2.2: Helical spring

(Jadhav et al., 2014)

The first automotive coil spring was on the model-T (Ford) in (Berti & Monti, n.d.). The advance coil spring material used had about 500 MPa design stress level. Coil spring materials have grown forward where today the design stress of around 1200 MPa in order to sustain the durability. Nowadays, most automobile company have high attention to reduce the weight of car components without changing the remaining system and coil spring was not exempted from it. In this case, the way to implement by reducing the spring wire diameter at same time sustain the mechanical properties of the coil spring. This effort ensues due to obtain the better performance of the automobile.

2.3 MANUFACTURING OF HELICAL SPRING

Regularly, the operating environment is the single most crucial consideration for proper spring material selection. In order to obtain the successful application, material must be highly adaptable with the environment and resists effects of temperature and corrosion without an excessive loss in spring performance. The spring reliability will reduce significantly influence by the corrosion and elevated temperatures. From this information, the proper material selection will be made in producing the helical spring. The determination of maximum allowable stress together with the load requirements and suitable dimensions will be selected.

The fundamental factor considered in the design of a spring is the strain energy of a material. The specific strain energy in the material is expressed as

$$U = \frac{\sigma^2}{2 \times \rho \times E} \tag{2.1}$$

From this equation can be consider that material having lower density (ρ) and Young's modulus (E) will be having quite higher specific strain energy under the same stress condition. The coil spring is made from rods which are installed wound as a helix. Rod width, spring measurement and the quantity of coil turns per unit length are the primary outline parameters of a coil spring.

Chiu, Hwan, (2007) was implement the study on four different types of helical compression springs made of rubber core unidirectional laminates (UR), unidirectional laminates (AU), rubber core unidirectional laminates with a braided outer layer (BUR) and unidirectional laminates with a braided outer layer (BU), respectively. The outcomes demonstrate that the spring with BUR failure load in compression to 18% alongside the upgrade of 16% in spring constant while for the helical composite springs with a rubber core has 12% more load bearing limit.

(Manjunatha, 2012) was investigate on the mechanical behaviour of three different types of springs manufactured using glass/carbon fibre, glass fibre, carbon fibre in 45-degree orientation with consist of the applicability of fibre reinforced plastic in springs. The spring rate of the carbon fibre spring is 24% more than the glass fibre spring and 10% high than the glass/carbon fibre spring.

2.4 SIGNAL

Signal is a series of number that come from measurement as a function of time. It is being measured by an analogue-to-digital converter to produce a series of signals at regularly spaced interval times as showed in Figure 2.3. The time series provide the information of statistical parameter by manipulating the series of discrete number. In the case of fatigue research, the signals are a form of information of measuring cyclic load, such as force, stress and strain against time.

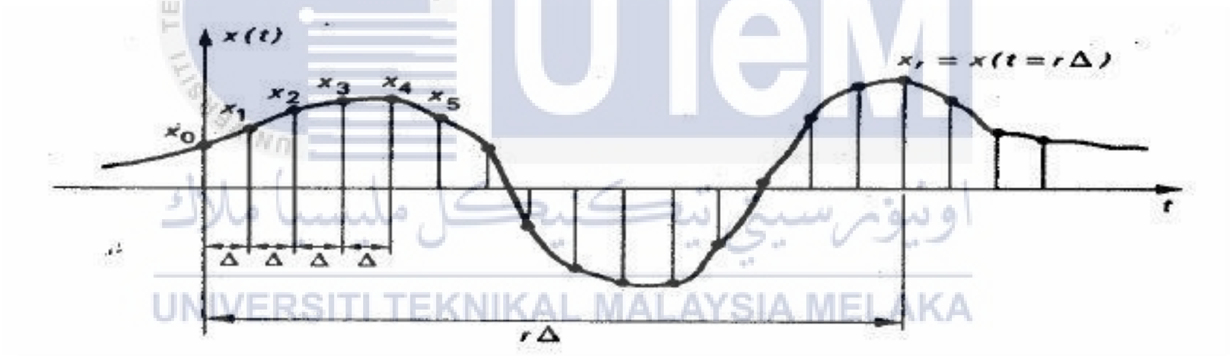


Figure 2.3: Sampling a continuous function of time at regular intervals
(Abdullah et al., 2005)

2.4.1 SIGNAL TYPE

Signals may be classified referring on the nature and characteristic in time domains. They are divided into two types, deterministic and nondeterministic as shown in Figure 2.4.

Deterministic signals also known as stationary signals. The signals have the steady frequency and degree of content over a long period of time. It also exhibits statistical properties which remain unchanged with t changes in time. It can further divisible into

periodic and non-periodic signals. Periodic signals have the pattern of wavelets which repeat at equal increment of times. It can be categorized into sinusoidal and complex periodic signals. Non-periodic signal has the waveform which varies over the duration of time. It is further divided into almost-periodic and transient.
Sinusoidal signal is represented mathematically by

$$x(t) = Xsin\ 2\mu f_{\circ} t \tag{2.2}$$

Where: X is the amplitude

$f\,o$ is the cyclic frequency

X (t) is the instantaneous value at time t

Complex periodic signal is the sum of the amplitudes of its component signal for each value of the independent variable. These amplitudes are related to the frequency and phase of the signal. The equation is presented by

$$x(t) = \sum_{n-1}^{\infty} Xn \sin(2\pi fnt + \theta n) \tag{2.3}$$

n=1,2, 3,

$f\,n$ is the cyclic frequency

θn is the phase angles

Almost periodic signal is similar to the complex periodic signal but it contains the sine wave of arbitrary equations which frequency ratios are not rational number. In other words, the frequency of one or more of the higher frequency components of the signal is not an integral multiple frequency of the signal's lowest frequency component. Transient signal is defined as non-periodic signal with a finite time range (Bendat et al. 2005). Transient signal includes all other deterministic data which can be described by a suitable function. This signal can be described by a step or ramp function. It occurs at a short period of time and then disappears. Transient signals can be square pulse, triangular pulse and sine pulse which decay to zero.

Non-deterministic signals are also defined as random signal as shown on figure 4. Most signals in nature exhibit the nondeterministic characteristic. A nondeterministic signal is occurred randomly and the wavelet is irregular. It can generally be classified into two categories, stationary and non-stationary. Stationary signal is the relevant statistical parameters remain unchanged for the whole signal length. Furthermore, stationary signal can be divided into two categories, ergodic and nonergodic. When one sample record of signals is completely representative of the entire process, the process is ergodic. The mean value and the autocorrelation do not differ. The mean value μ_χ (k) is mathematically defined as

$$\mu_x(k) = \lim(T \to \infty) \frac{1}{T} \int_0^T X\kappa\,(t)dt \tag{2.4}$$

and the autocorrelation function is

$$R_x(\tau, k) = \lim(T \to \infty) \frac{1}{T} \int_0^T X\kappa\,(t) X\kappa(t+\tau)dt \tag{2.5}$$

Where: τ is the time displacement

T is the period

k is the number of sample function

Non-stationary signal is ones who amplitude and frequency vary with times. It can be divided into mildly non-stationary and heavily non-stationary. According to (John, 2010) mildly non stationary signal is a random process with stable mean, variance and root mean square value for most of the record, but with short periods of changed signal statistic due to the present of transient behaviour. Heavily non-stationary signal is defined in a similar manner to mildly non-stationary signals but it is characterised by the presence of more transient events.

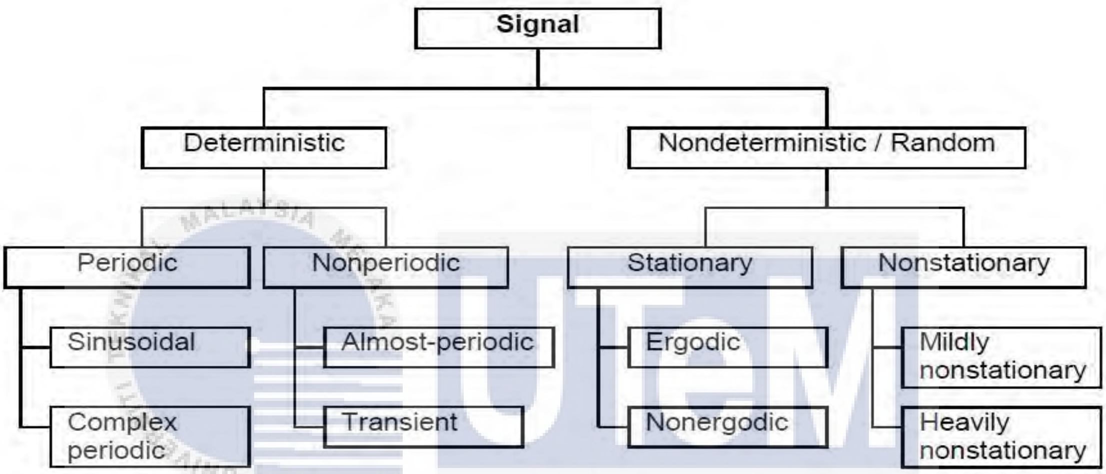


Figure 2.4: Typical signal classification

(Abdullah et al., 2005)

2.4.2 STATISTICAL ANALYSIS

In generally could be say that statistics is the methodology for collecting, analysing, illustrating and making conclusions from some information with present of data. Statistics is a very extensive subject comes out with applications in a variety of number of different fields. Other than that, statistics can be name as one of methodology which mathematicians and scientists have developed for interpreting and making a conclusion on the data collection. The suitable way to learn statistic is by taking course and work with the data collection.

Generally, the point related to the statistical analysis are mean, the Root-Mean-Square (RMS), maximum and minimum value, standard deviation and variances which can be get from the sample and population (Barbero et al, 2000) In this paper the author used the Weibull statistic and this method had been applied in designing mechanical components made of composite materials. The two Weibull parameter distribution been used regarding the sample size to describe the strength properties of the materials. Basically, the main objective of statistics is to obtain the conclusion about the population from an analysis of information contained in sample data. These also involve the evaluation of the uncertainty that present in the conclusion.

2.5 FATIGUE

Fatigue is one of the common failures that occur in plenty of materials. The mechanism of fatigue could be described in condition where a material achieved fails or crack because of repeated cyclic stresses being applied under the ultimate strength of the material. Generally, it ensues by fluctuating strain and stress at some point and will allowed cracks or fracture exist after enough number of fluctuations. Fatigue failure usually occurs quite suddenly with disastrous outcome based on the crack propagation.

The specimen can return back to its original condition when the load is release. This is occurred because of the maximum stress in the specimen does not greater the elastic limit of the material. The fluctuating loading that been applied will be continuously repeated when stresses remain in the elastic range. The fatigue is considered as high cycle if the number of load cycles to failure is more than 1000 cycles while the fatigue is considered as low cycle if the number of load cycles to failure is not more than 1000 cycles. In such cases, cracks will ensue at a stress which lowers than static breaking strength. This phenomenon is called as fatigue (Abdullah et al, 2012).

2.6 FACTOR AFFECTING THE FATIGUE LIFE

(Chetan et al., 2012) was clarify that there are some of parameters which can influence the fatigue life of the structure which are surface quality, material type, residual stresses, cyclic stress state, geometry, size and distribution of internal defects, direction of loading, grain size, temperature, and environment. The crack nucleation will be occurring in microscopically small scales size when loading had been applied on a material. The crack propagation approach will grow faster at the time and will affect the durability of the structure.

2.7 FATIGUE DAMAGE

There are three basic approaches have been used to analyse fatigue damage, such as stress-life approach (S-*N)*, strain-life approach (ε -*N)* and linear elastic fracture mechanics (LEFM). *S-N* approach is first formulated in the 1850s to 1870s. The nominal stress had been used quite more than local stress to understand and quantify metal fatigue. The method does not functionally well in low cycle application. (Taib et all., 2010)

Fatigue damage is derived from the number of cycles to failure. The fatigue damage caused by each cycle of repeated loading is calculated by reference to material life curves, such as *S-N* or ε-*N* curves. The fatigue damage *D* for one cycle is calculated as:

$$D = \frac{1}{Nf} \tag{2.6}$$

and the total fatigue damage ΣD caused by cycles is expressed as (Abdullah, 2005):

$$\sum D = \sum \frac{N_i}{Nf} \tag{2.7}$$

N_i is the numbers of cycle within a specific stress range and mean. Therefore, if fatigue damaging values have the range (0 - 1) where zero denotes no damage meanwhile 1 means total failure (one cycle to failure). In strain cases, based fatigue life prediction, current industrial practice uses the Palmgren-Miner linear cumulative damaging rule normally associated with the established strain-life fatigue damaging models, such as the Coffin-Manson.

The fatigue life is generally divided into three stages/periods as shown in Figure 2.5

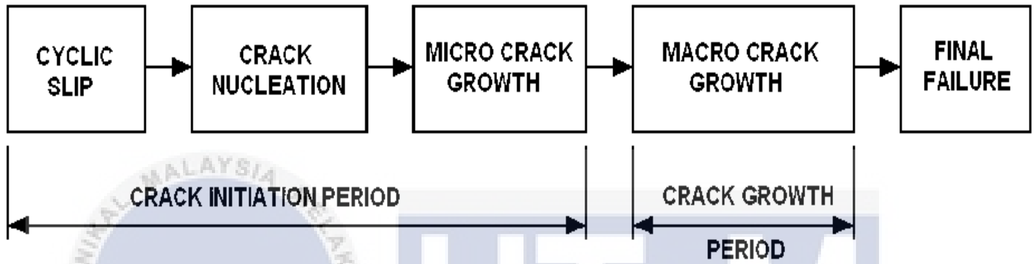


Figure 2.5: Stage of fatigue life

(Del Llano et al.,, 2007)

2.7.1 Stress-life based approach (S-N Method)

For the fatigue design and components, several methods are available. All require similar types of information. These are the identification of candidate locations for fatigue failure, the load spectrum for the structure or component, the stresses or strains at the candidate locations resulting from the loads, the temperature, the corrosive environment, the material behaviour, and a methodology that combines all these effects to give a life prediction. Prediction procedures are provided for estimating life using stress life (Stress vs. Number of cycle's curves) as shown in Figure 2.6, hot-spot stresses, strain life, and fracture mechanics.

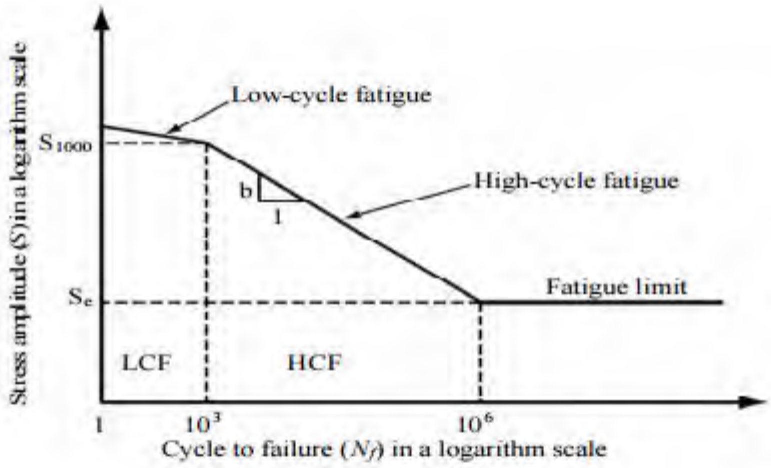


Figure 2.6: S-N graph

(Taib et al., 2010)

2.7.2 Strain-life based approach (ε-N Method))

This method is more related and definite investigation of plastic deformation at confined districts where the stresses and strain are considered forever evaluates. This strategy is particularly useful for law cycle weakness application. The Strain-Life strategy depends on the perception that in numerous segments the reaction of the material in basic areas such as notches is strain or deformation dependent. In the Strain-Life approach the plastic strain or deformation is straight forwardly been measured and evaluated. The Stress-Life approach does not represent plastic strain.

The local Strain-Life approach has picked up acknowledgment as a helpful strategy for assessing the fatigue life of a notched part. Both the American Society for Testing and Materials (ASTM) and the Society of Automotive Engineers (SAE) have prescribed strategies and practices for leading strain-controlled tests and utilizing this information to predict fatigue lives.

Del Llano-Vizcaya et al. (2007) was undergo a test examination been led to survey the stress on helical spring fatigue properties. To start with S–N bends were resolved for springs treated under various conditions in term of times and temperatures on a testing machine. The assessment had been made on stress repose on spring cause by cyclic stacking. This strategy utilized as a part of the test work and methodology utilized as a part of the relaxation tests, fatigue tests and residual stress measurement. At long last residual were measured on the inward and external loop surfaces to dissect the impact of heat treatment.

Shimatani et al. (2010) was displayed two sorts of example were prepared by processor and cutting apparatus, both examples demonstrated clear duplex S-N bend, made out of three or two sorts of disappointment mode relying upon the stress amplitude, for example, a surface consideration incited failure mode (S-mode), a subsurface incorporation actuated failure mode without (Imode) and with granular bright facet (GBF) zone in the region of inclusion (IG-mode). Fatigue life in high-cycle administration was practically same between the both materials cause of presence of practically same size inclusion at crack origin.

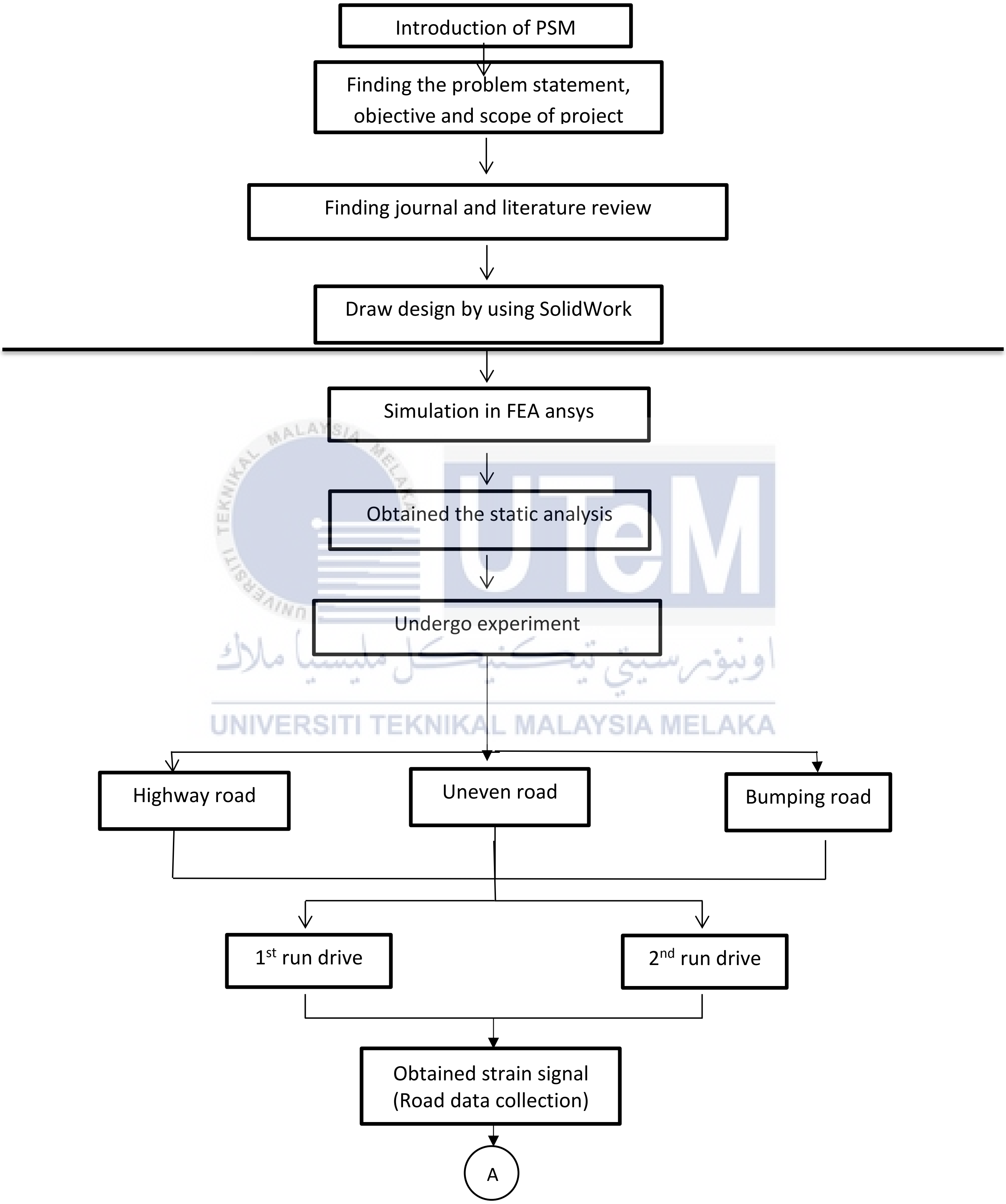
CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In order to achieve the objectives of this project, there are several methods lists in the flowchart, as shown in Figure 3.1 that should be implemented. In this flowchart, the initial step was finding the related journal. Then, perform the drawing of the spring using Solid Work. The critical area should have been obtained by finite element analysis using Ansys software. The road data strain signal result will be obtaining by placing the strain gauge at the critical area on the helical spring and the data will be imported to the Design Life software. The characteristic of the fatigue strain signals will be determine using statistical method. Lastly, the fatigue life of car suspension system will be predicted. The comparison can be performing between the static analysis and road data strain results. If the strain result was almost the same in the critical area, then it can be considered as validation for the finite element analysis part. Then the model can be used in modal frequency response analysis.

3.2 Flow chart



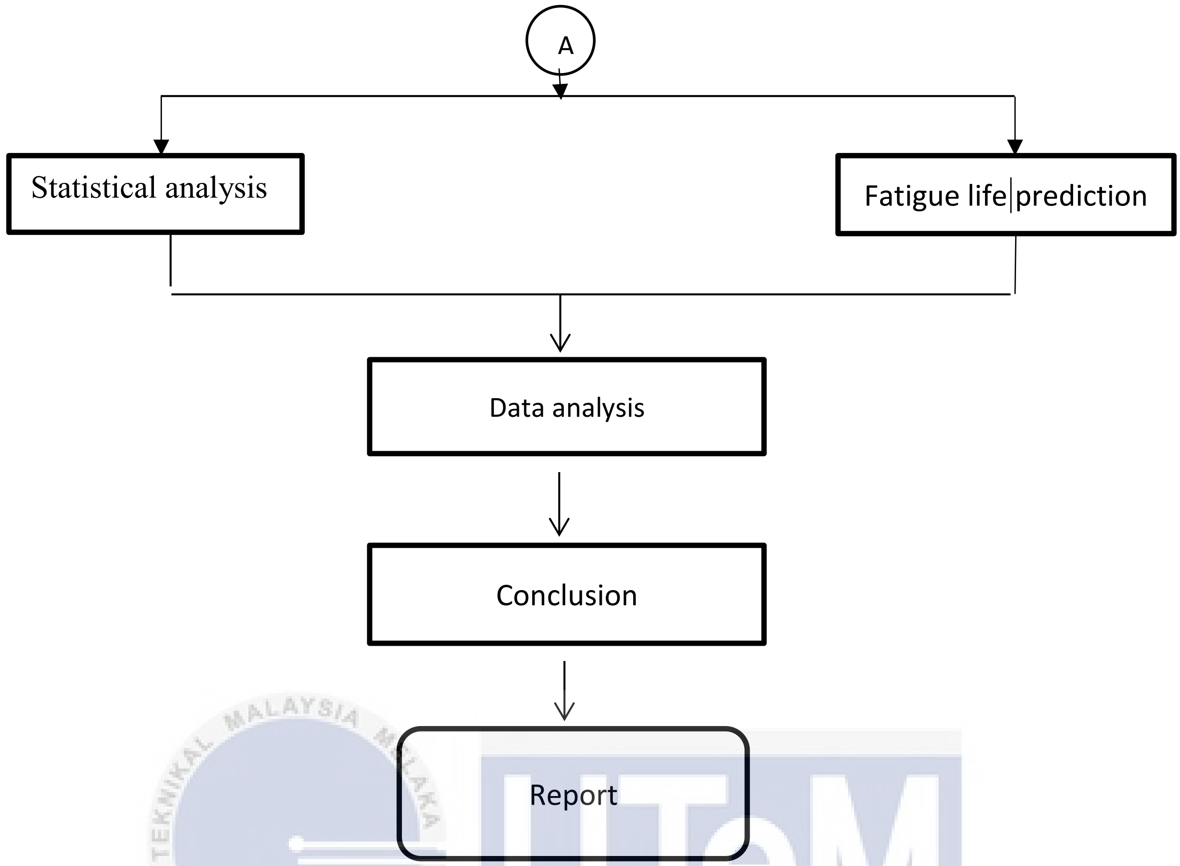


Figure 3.1: Flow chart methodology

The way to implement this project is by determined and reviewed a journal, articles or any sources regarding to the project significant. The journal that related to the suspension system, statistical analysis, and fatigue failure and fatigue life had been chosen mostly in order to gain more understanding. The journal that had been selected had been continued to identify the purpose of study, method used and the result. From that point, the parameters and any mechanisms can be obtained clearly. Then, the project had pursued to ensure the correct result will be obtained.

3.3 Measurements of Spring

Figure 3.2: Measurement of spring clearance

Figure 3.3: Measurement of spring thickness

Figure 3.4: Measurement of spring diameter

The measurement of the spring must be done in order to get the actual sizing. The spring suspension of Perodua Myvi 1300cc had been used to determine the diameter of the coil, pitch and length of the spring as shown on Figure 3.2. All this geometry is important in order to get the accurate measurement. The tools that will be used in getting the measurement and dimension are meter tape and digital calliper as shown on Figure 3.3. Digital calliper is used because easy to handle besides producing an accurate measure within 2 decimal places.

3.4 Drawing using Solid work

The helical spring parts of suspension been drawing using Solid Work software. The drawing of helical spring will be follow the sizing and specification of Myvi car model as shown on Figure 3. 5. This is because the experiment will be run by using Myvi 1500cc car model. The specifications and dimensions is shown in Table 2.1

Spring Clearance($\mathcal{A}$)	27mm
Spring Diameter ($\mathcal{B}$)	83mm
Spring Thickness ($\mathcal{C}$)	12mm

Table 2.1: Table of dimension

Figure 3.5: Spring specifications

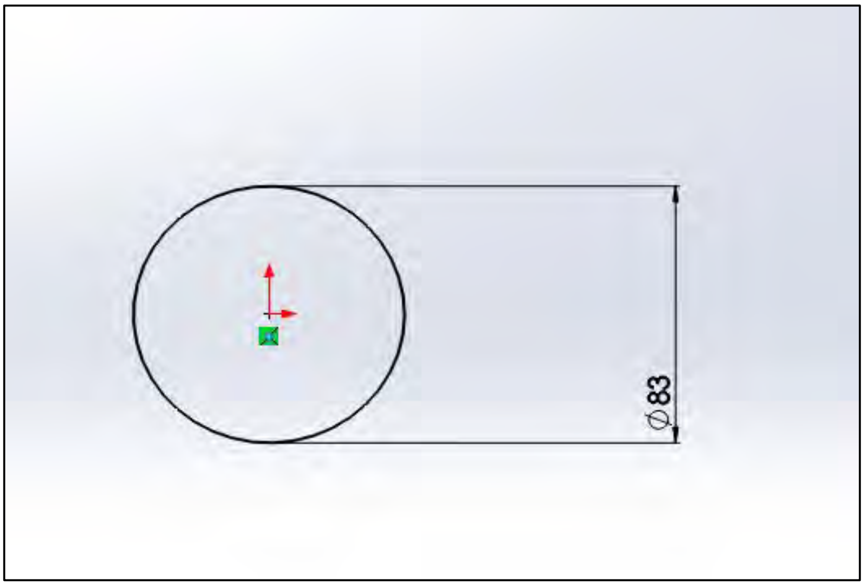


Figure 3.6: Drawing of diameter

The first step is select a front plane and then draw the circle with a diameter of 83mm as shown on Figure 3.6.

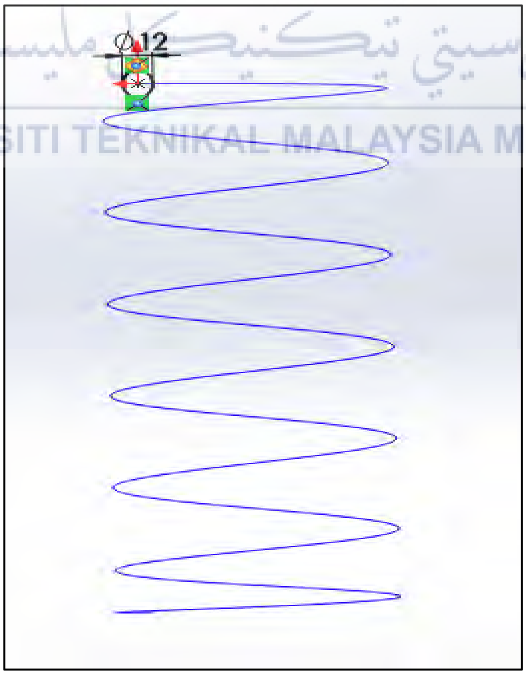


Figure 3.7: Drawing of helix and spiral

The next step is select the feature of helix and spiral and the length of the spring as shown on Figure 3.7.

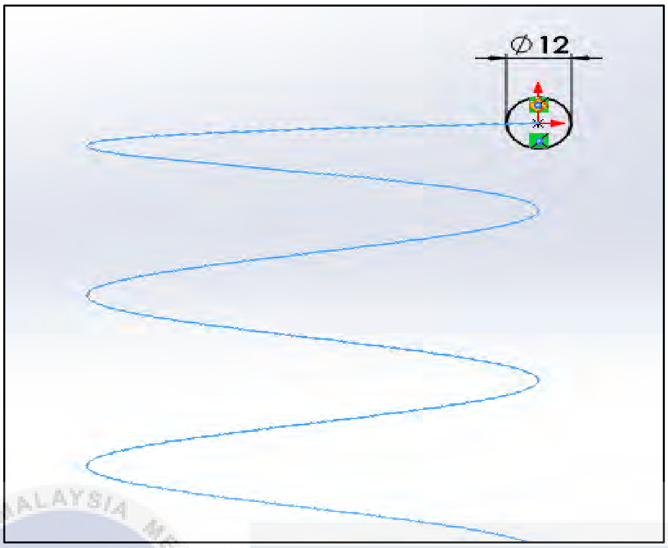


Figure 3.8: Insert the thickness of spring

Then, insert the thickness of the spring with is 12mm as shown on Figure 3.8 and then select swept boss features to make a full spring coil shape as shown on Figure 3.9 below.

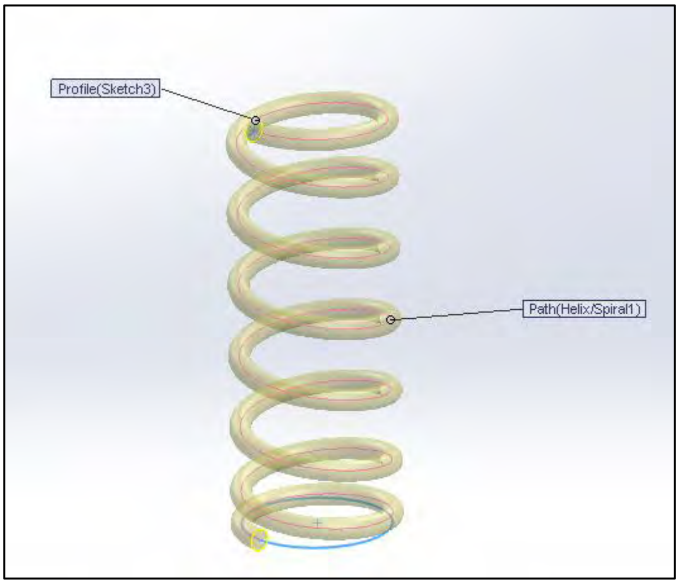


Figure 3.9: Select a swept boss feature

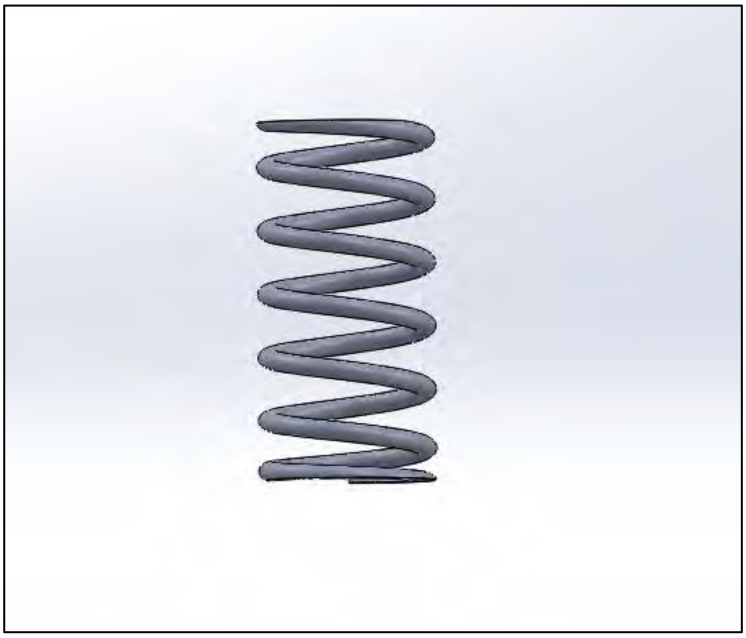
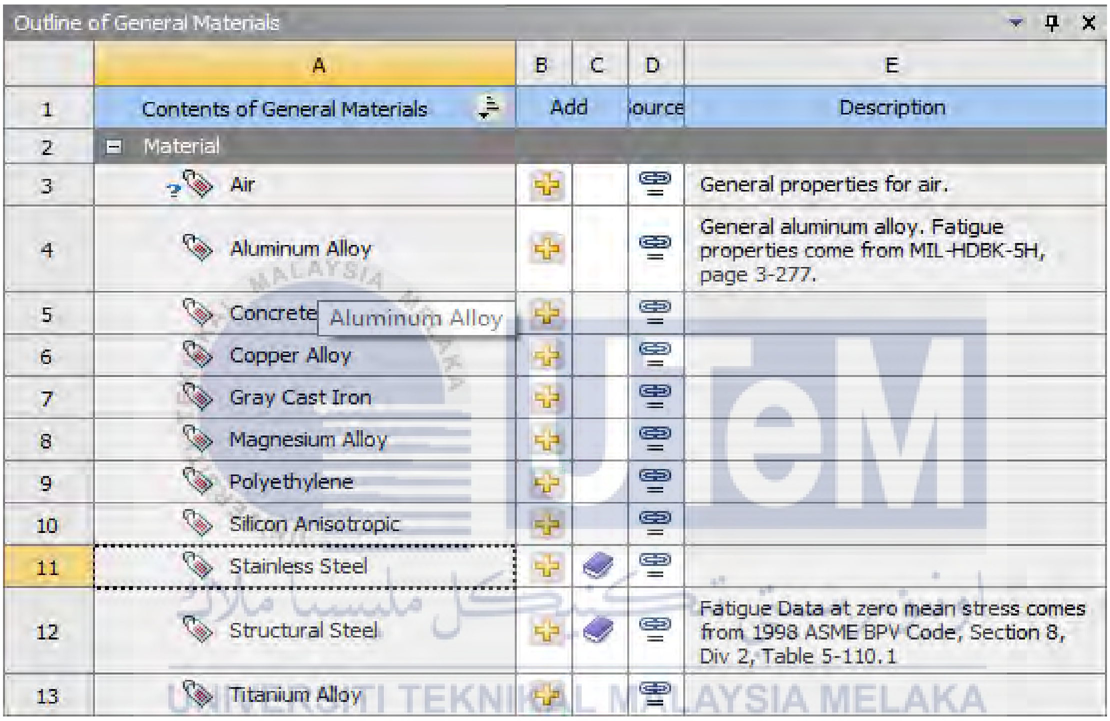


Figure 3.10: Full drawing of spring

Drawing of spring is already done by using Solid Work software as shown on Figure 3.10 and then the next methodology can be proceeded to achieve the objective. In order to get an accurate and precise geometry for the spring, the drawing must be saved as IGES format before import to Ansys workbench software.

3.5 Static Analysis using Ansys

Once drawing is done inside Solid Work, the drawing will be import to Ansys Workbench in IGES file. This file is chosen to ensure the analysis can be done without any problem. At first, select the general material at engineering data sources as shown on Figure 3.11. Stainless steel will be used in this study. Table shows the properties of stainless steel which already stored in the Ansys library databased.



Outline of General Materials

	A	B	C	D	E
1	Contents of General Materials	Add		ource	Description
2	Material				
3	Air				General properties for air.
4	Aluminum Alloy				General aluminum alloy. Fatigue properties come from MIL-HDBK-5H, page 3-277.
5	Concrete				
6	Copper Alloy				
7	Gray Cast Iron				
8	Magnesium Alloy				
9	Polyethylene				
10	Silicon Anisotropic				
11	Stainless Steel				
12	Structural Steel				Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
13	Titanium Alloy				

Figure 3.11: Table of general materials

Name:	Stainless Steel
Tensile Yield Strength (MPa)	207
Compressive Yield Strength (MPa)	207
Tensile Ultimate Strength (MPa)	586
Density (kg/m³)	7750
Young's Modulus MPa	1.93e+005
Poisson's Ratio	0.31

Table 2.2: Mechanical properties of stainless steel

Start the analysis by select the static structural feature. A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. Firstly, put the fixed support at the bottom of the spring coil as shown on Figure 3.12. After that load will be apply onto the spring by 2000N as shown on Figure 3.13 refer to the related journal. Next, the spring coil will be meshing. The quality can be chosen at sizing method either course to fine mesh as shown on Figure 3.14. The fixed type is choosing as the size function because it more precise as shown on Figure 3.14. The tetrahedron method is the most type of method been used due to accurate result obtain as shown on Figure 3.15. After all the parameter been applied, the analysis can be solved for obtaining the Von-Mises stress.

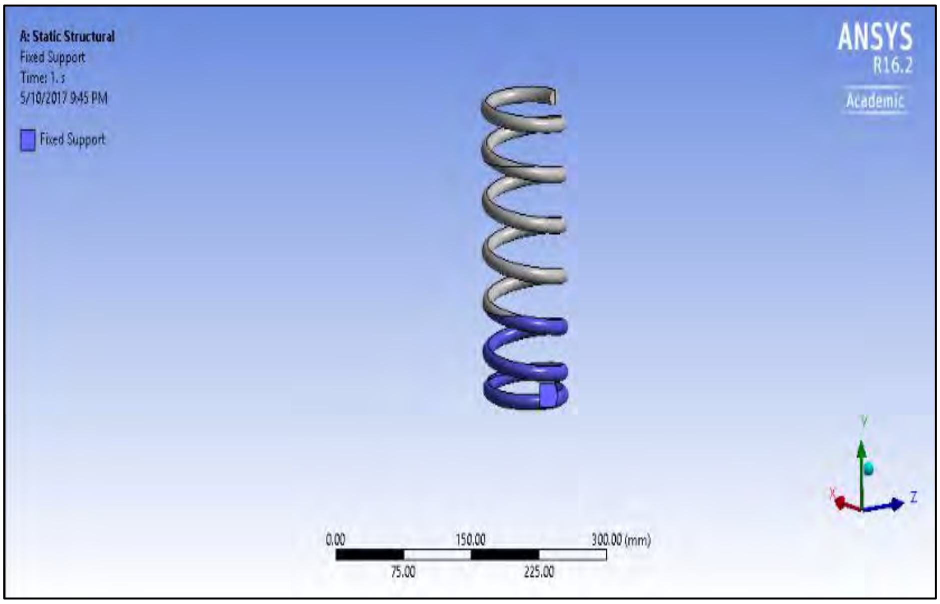


Figure 3.12 Fixed support

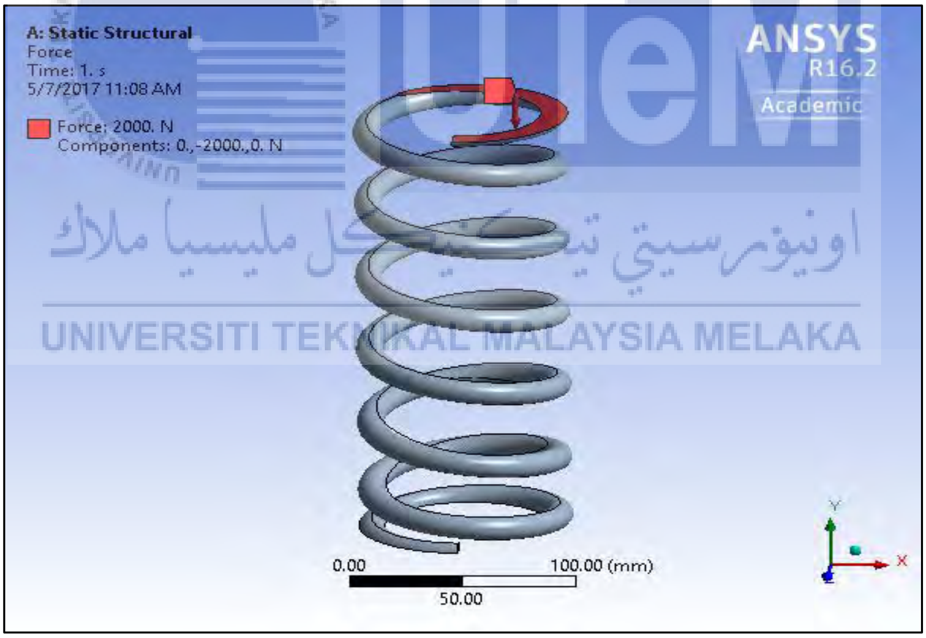


Figure 3.13: Force apply to spring

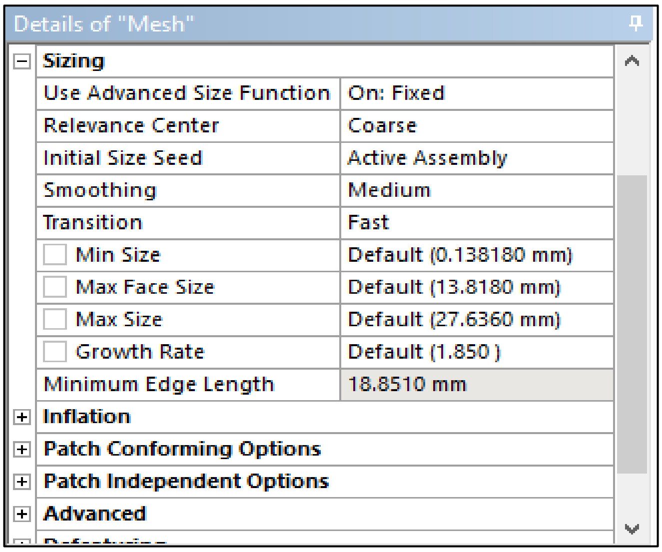


Figure 3.14: Meshing sizing

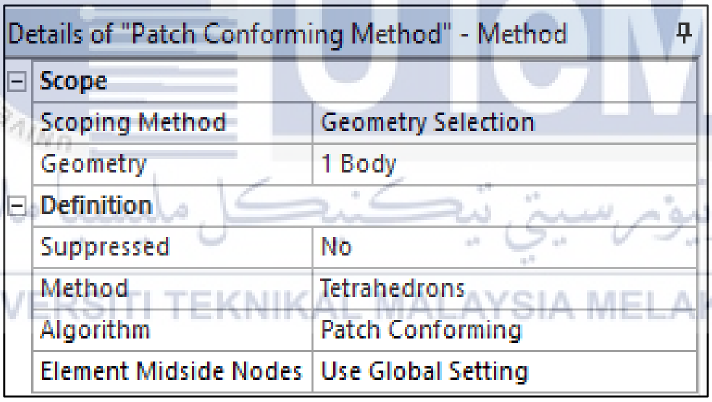


Figure 3.15: Meshing method

3.6 Preparation for removing spring

3.6.1 Removing wheels

The car need to be park in the clean and safe place to prevent any injury happen when undergo the experiment. Make sure the car in clear gear to avoid from rolling or sliding during experiment. Lug nuts need to be open a little before jack up using car lift. Identify the correct sizing to open all the nuts to prevent any damage of the components. After remove the nuts, the tire can be remove out.

3.6.2 Removing brake disc and brake calliper.

The brake disc and brake calliper need to remove first before remove the spring absorber. The car need to lift higher to easy access. Spindle nut at the centre of the brake disc must be remove properly. Then, the brake disc can be remove completely. As shown on Figure 3.16, a tie rod relates to steering knuckle and steering shaft.in safety step, tie rod need to be loosen a little bit to avoid brake disc fall. In the brake calliper section, upper and low nut need to pull out for easily remove the brake pad. After that, the spring absorber can be pull out easily as shown on Figure 3.17. The safety can more be taken such as wearing glove to avoid any injury during remove the components.

Figure 3.16: Pull out brake disc

Figure 3.17: Spring absorber

3.7 Installation of strain gauge

Strain gauge was used to measure the value of strain on the object or components. Strain gauge also convert force, tension, compression and weight onto electrical input that can resist from any external factor. Strain gauge is widely application for measuring the change in displacement and can converting into resistance, inductance or capacitance.

There are two type of strain gauge that always been used in engineering field. In electrical resistance device consists of thin wire placed on flexible paper tissue and been attached to variety the strain material. In the electrical resistance, it has Wheatstone bridge and it can be adjusted in three different ways such as full bridge, half ridge and Quarter bridge. The strain gauge that will be use in this project as shown on Figure 3.18.

Figure 3.18: Strain gauge

Before attach the strain gauge to the spring absorber, the surface area of the spring need to be clean smoothly to get the accurate result. This step must be done to remove all the dust and impurities that be found on the surface. Clean by using clean paper or tissue is most suitable to avoid the scratch. After that, place the strain gauge at the most critical part on the spring that have been identify by using Ansys as shown on Figure 3.19.

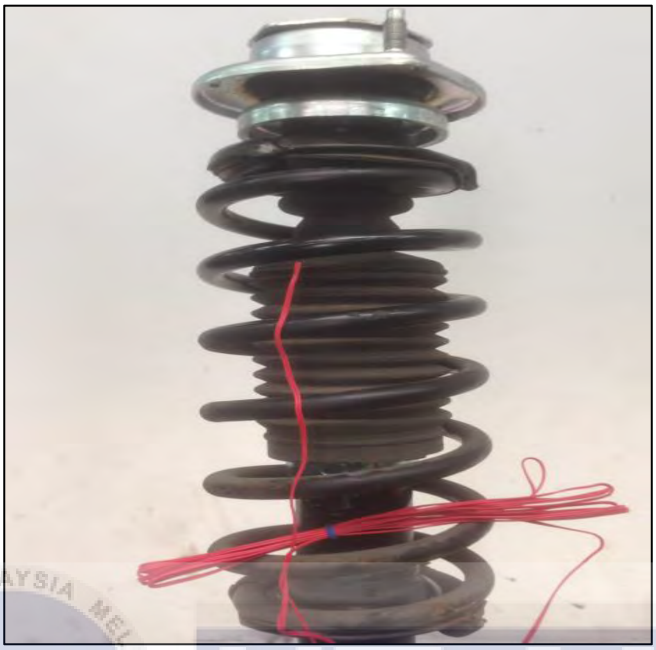


Figure 3.19: Place the strain gauge at spring

Then, place back the spring correctly to avoid any fault as shown on Figure 3.20. In a way to ensure the strain gauge can attach properly for a long period of time, use adhesive glue and sell tape. Rap the wire correctly for secure to inhibit it disconnected during undergo the experiment.

Figure 3.20: Place the spring back

3.8 Wiring Connection

Wire is very sensitive and easy to disconnect. Therefore, the connection of strain gauge and data acquisition must be design properly to avoid from disconnected during experiment. As shown on Figure 3.21, all wire is being wrap and mount by glue properly. Cable tie also been used to ensure it can attach strongly. Then, the wires will be insert through the front body of the car and been attach to the data acquisition as shown on Figure 3.22. The laptop will be turn on and connect to the data acquisition as shown on Figure 3.23.

Figure 3.21: Strain gauge flow

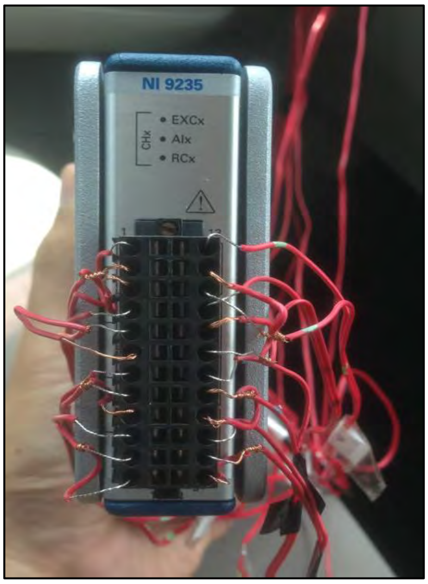


Figure 3.22: Strain gauge on data acquisition

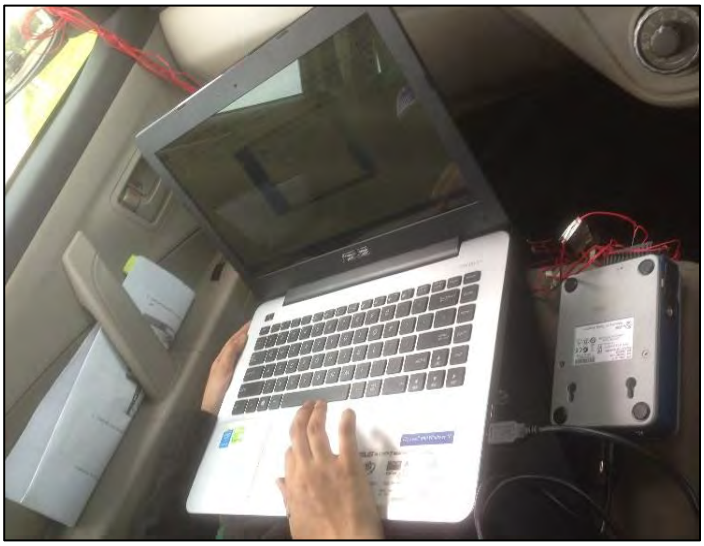


Figure 3.23: Connection of data acquisition and laptop

3.9 Obtaining Fatigue Strain Signal

Strain can be measured and has been shown to be well correlated to low-cycle fatigue. Finite element analysis was performed to identify the critical area to choose location for mounting strain gauge. Frequency for strain signal must be in suitable range to improve accuracy data input that must be more than 400Hz. All the step must be done properly to obtain an accurate result.

3.9.1 Layout of Data Acquisition

Data acquisition system (DAQ) consist of code that allowed interacting with hardware. DAQ used Ni-DAQmx driver software and driver software which used to communicate between hardware connected to the computer. Labview software will be use as programming software. The DAQ have 8 channels and can be used simultaneously. In this project, the type of DAQ been used is NI 9235 as shown in Figure 3.24.

Figure 3.24: Data acquisition

3.9.2 Testing the signal

Firstly, test the hardware to know either the connection of strain gauge and the DAQ are properly connected. There are few step to be follow before undergo the experiment.

1. Make sure the hardware is connected with the laptop correctly by using universal serial bus(USB)
2. When it connected properly, notification about device detected will appear
3. Select configuration and test this device as shown in Figure 3.25

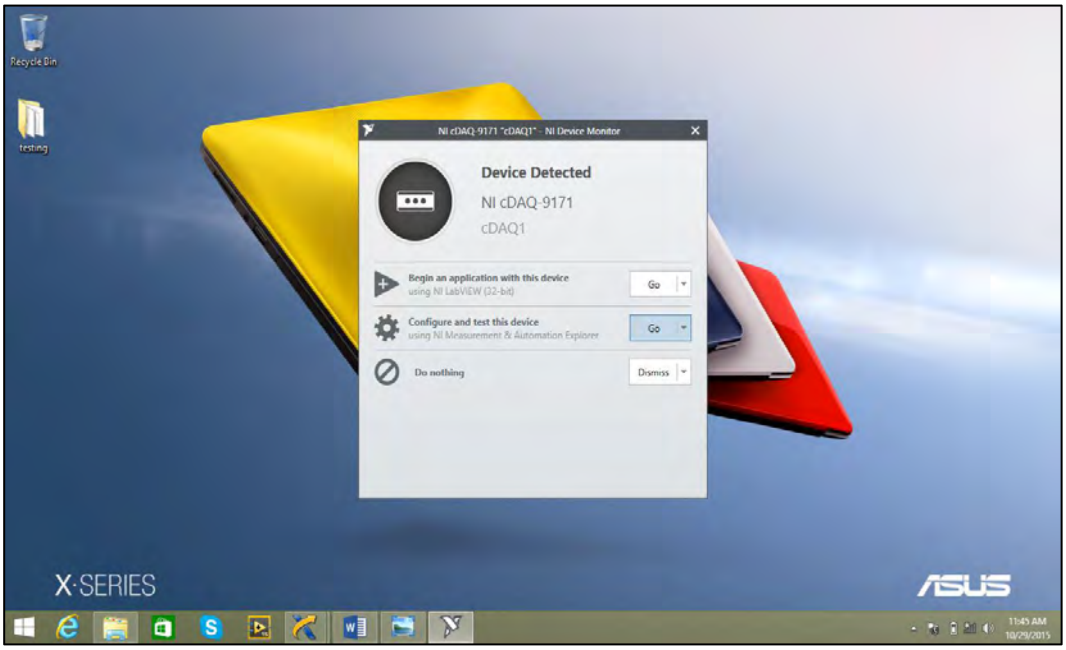


Figure 3.25: Select "configure and test this device"

4 After selecting configuration and test complete, the notification of properties will be shown as shown on Figure 3.26. Pursue by selecting slot detail.

5 Then, diagram about hardware will show. Click test panel in order to test connection between strain signal and channel are functioning as shown on Figure 3.27.

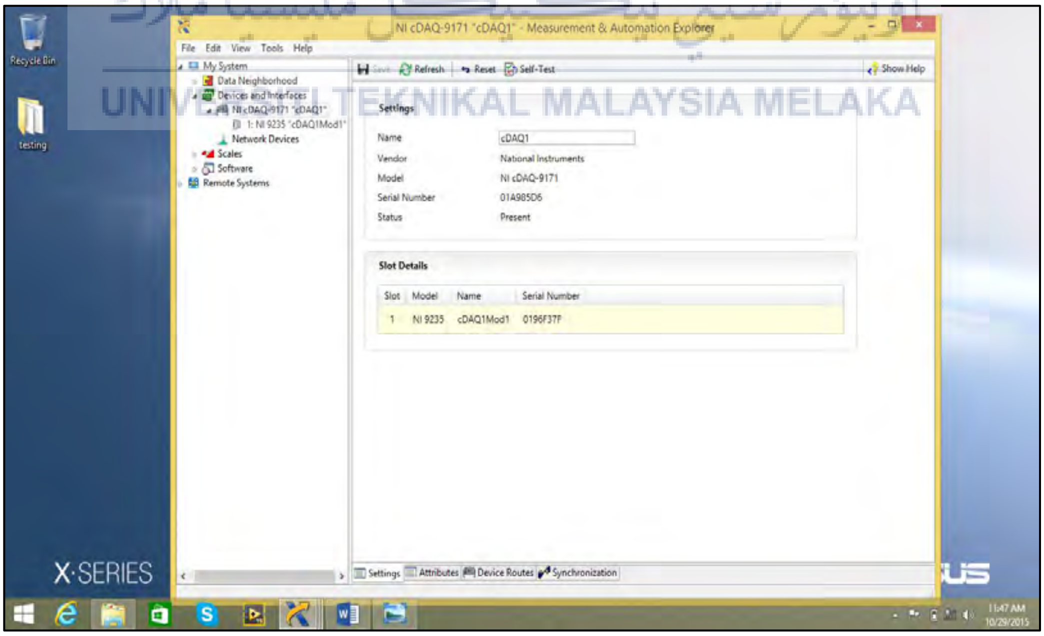


Figure 3.26: Slot details

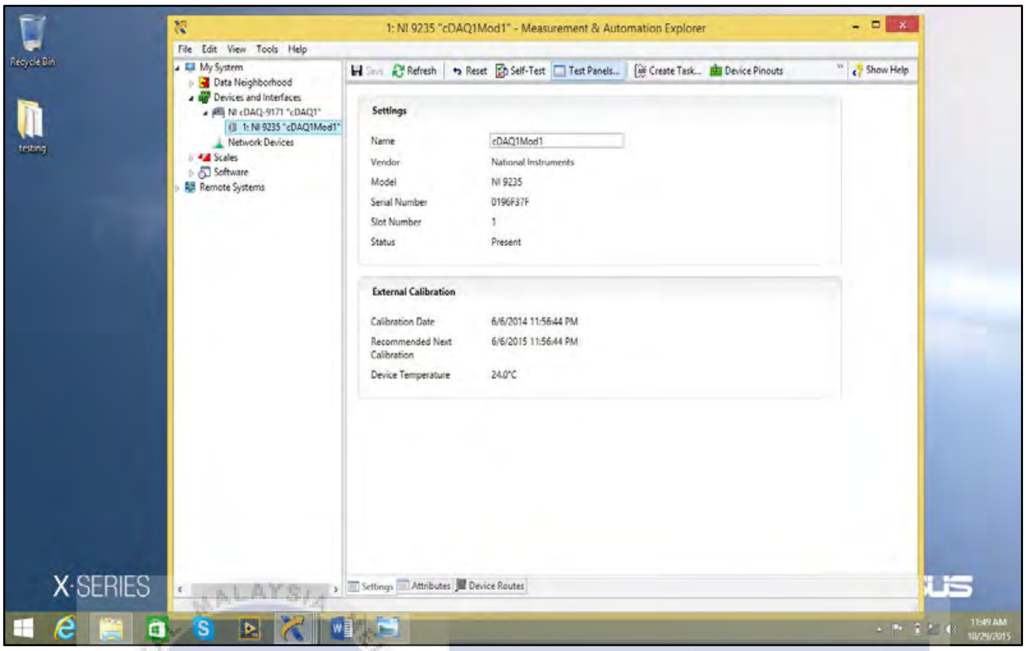


Figure 3.27: Test panel 1

6 After clicking on the test panel, diagram test panel will be shown. If it connected properly, the strain signal will appear amplitude versus sample chart as shown in Figure 3.28. Click on start and when chart moving it proving the hardware is working correctly as shown in Figure 3.29. If there is no signal appear, the connection of strain gauge and channel must be checked.

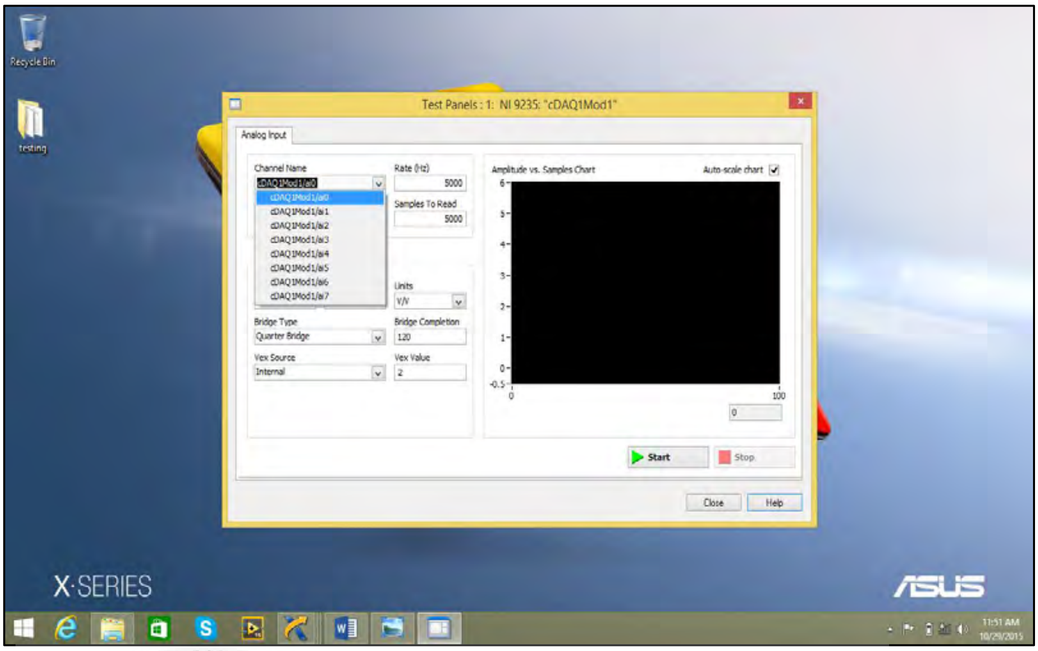


Figure 3.28: Test panel 2

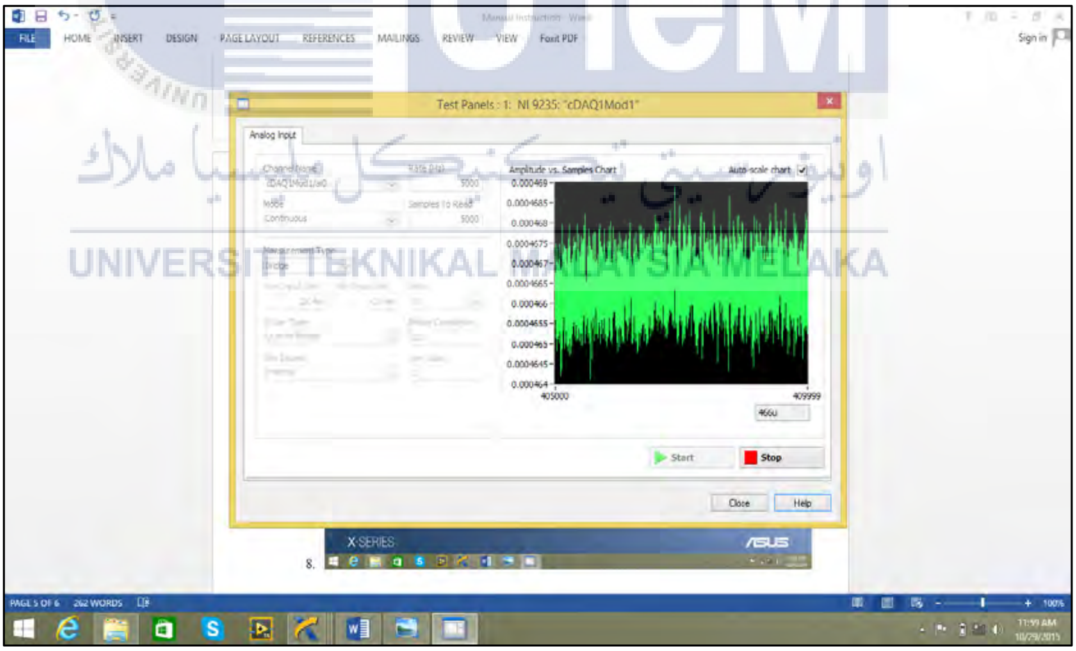


Figure 3.29: Frequency chart

3.9.3 Software Setup for Multiple Channels

1) Open NI-DAQmx and create a new task by select the create task as shown on Figure 3.30. There will be pop up window appear which require to choose either acquire signal or generate signal. Select the acquire signal.

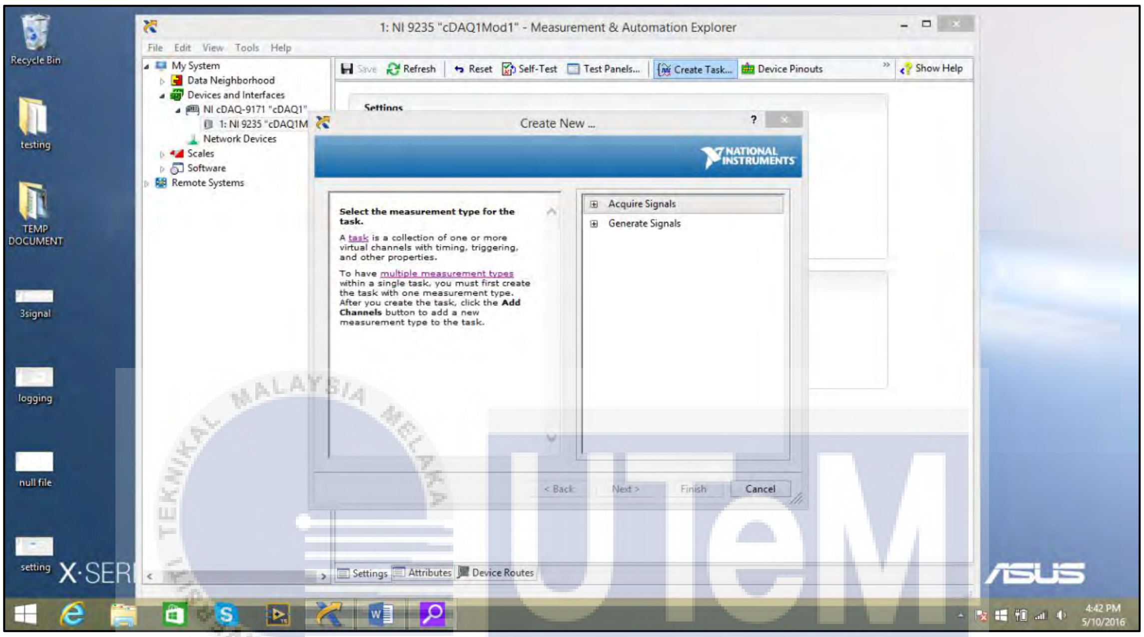


Figure 3.30: Selecting Create Task and Acquire Signals

2) Choose channel that need to be used as shown in Figure 3.31 and create name task as shown on Figure 3.32.

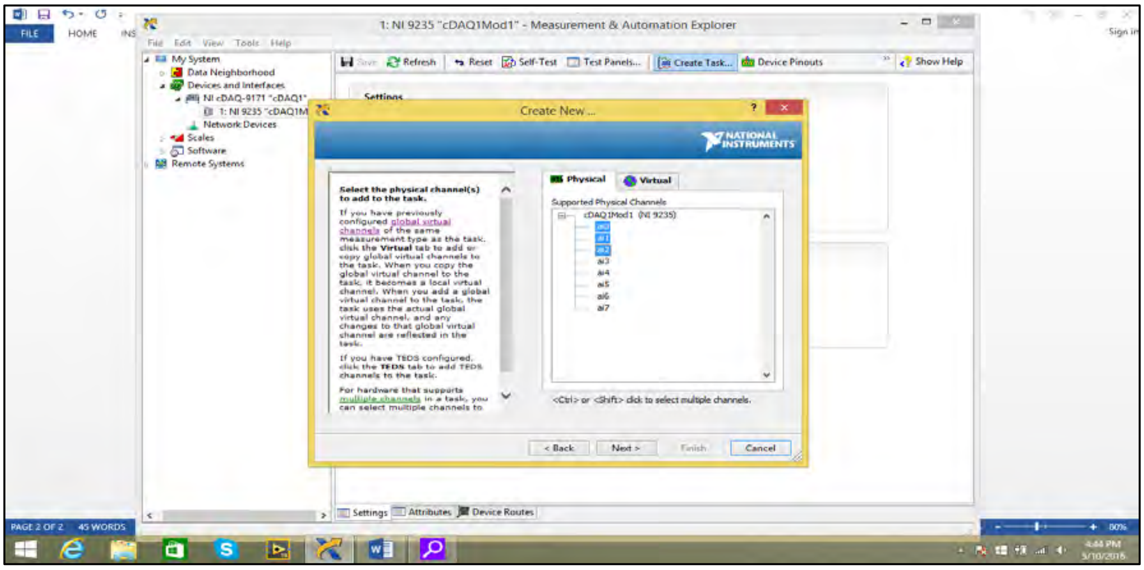


Figure 3.31: Selecting Channels

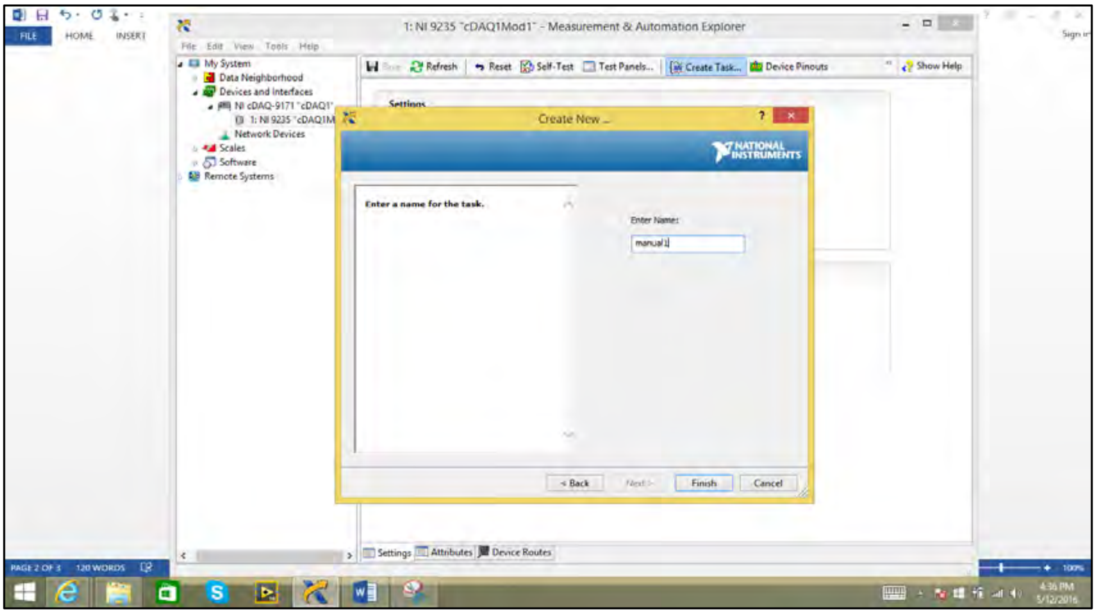


Figure 3.32: Rename the task

3) All channels that have been selected will pop up. The signal input range, gage factor, gage resistance and voltage can be change for each channel as shown in Figure 3.33. In this project gage factor must be set as 2 and gage resistance 120. Choose log and read in column logging to identify the characteristic of signal as shown in Figure 3.34.

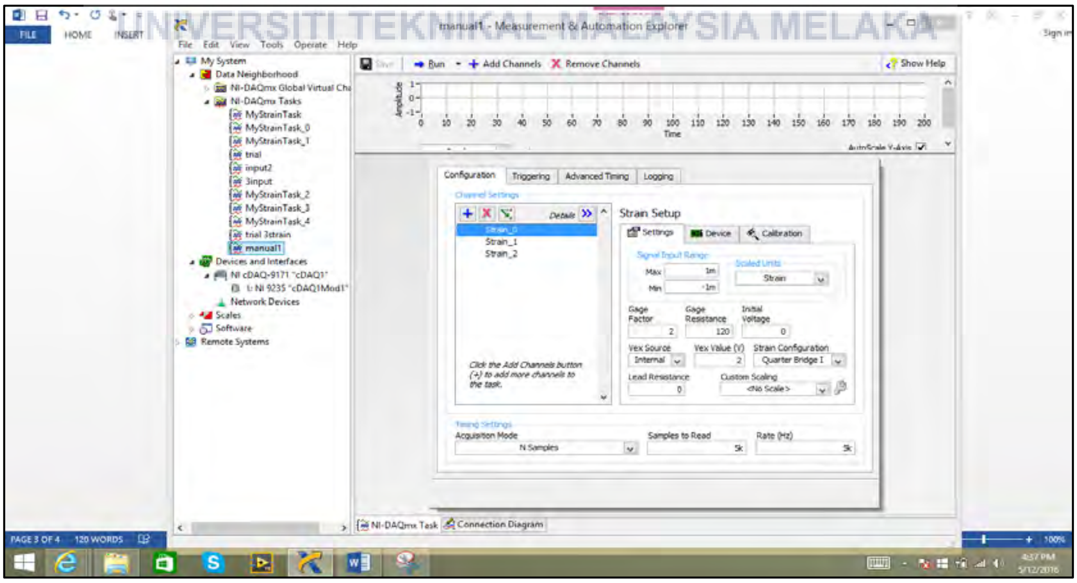


Figure 3.33: Configuration each Channels

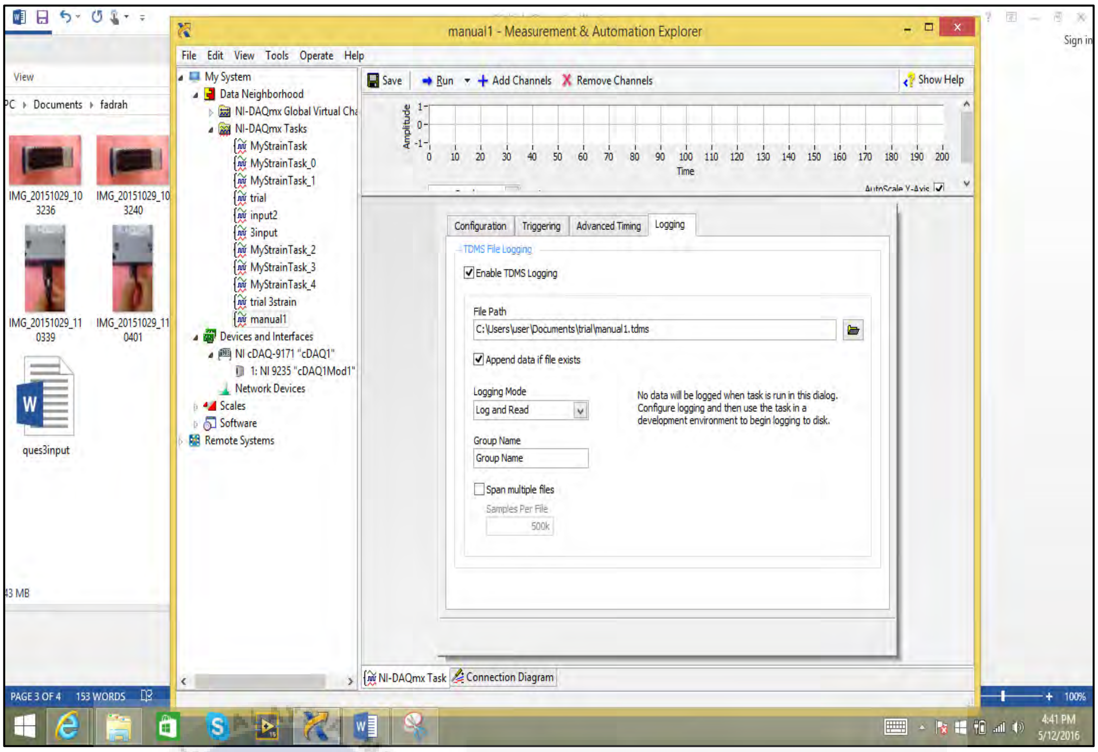


Figure 3.34: Logging Mode

4) Opening Labview software and select new VI as shown on Figure 3.35. Then, pop up of block diagram and front panel will appear as shown on Figure 3.36.

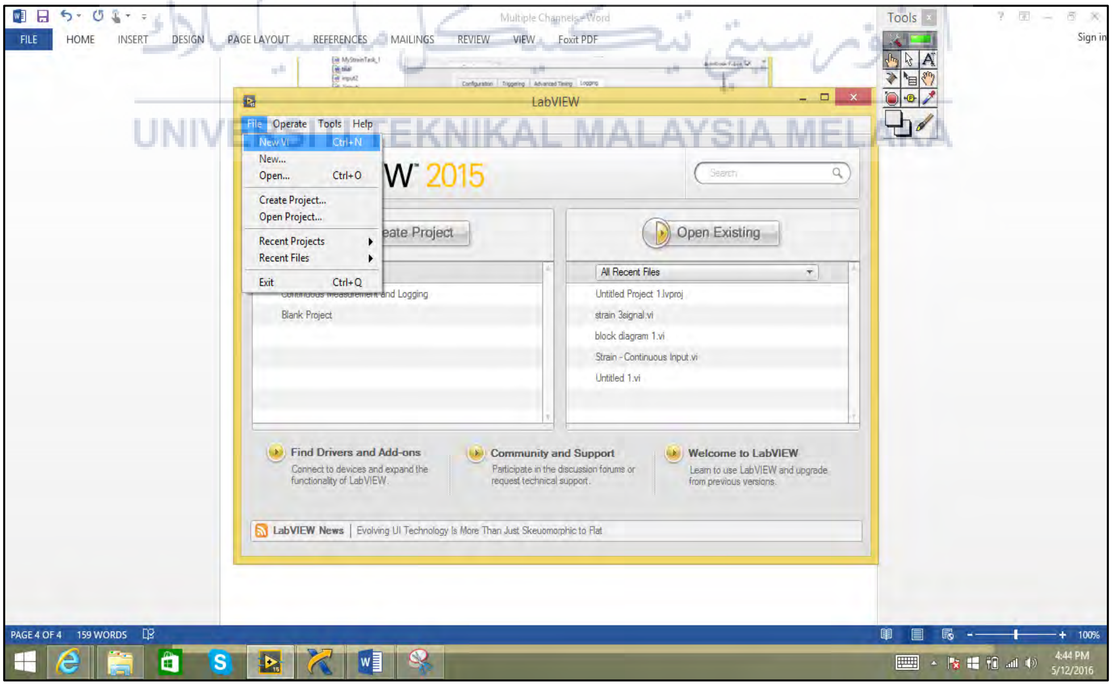


Figure 3.35: Opening Labview

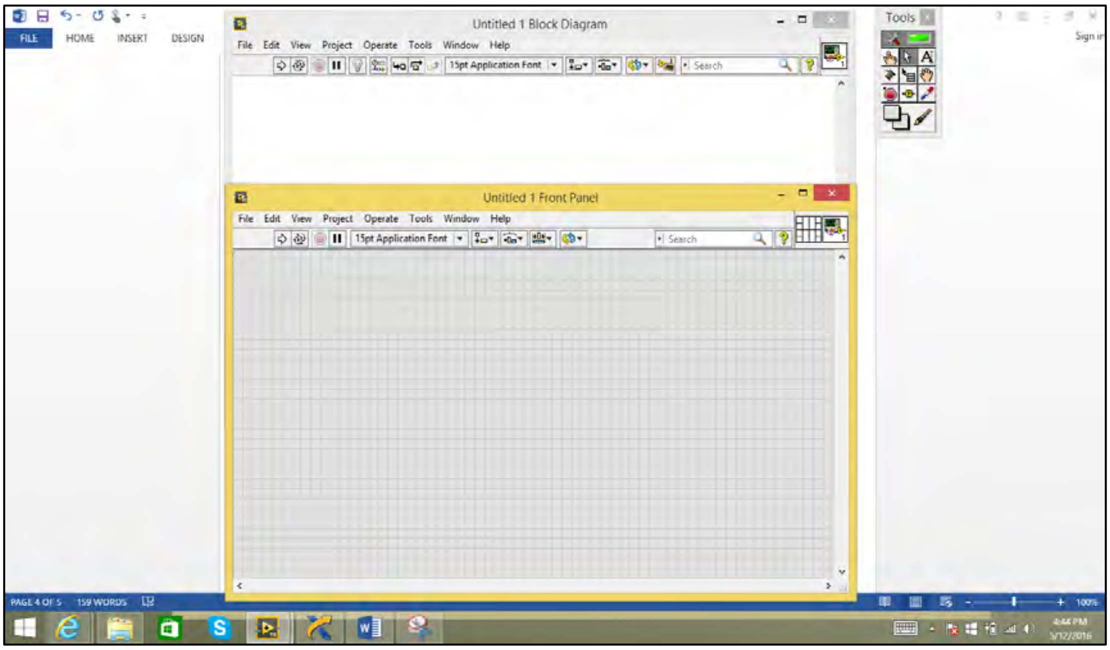


Figure 3.36: Block diagram

5) Open block diagram panel and select function pallet. Then, continue by select measurement I/O, NI-DAQmx and task constant as shown on Figure 3.37. Task constant need to be dragged to block diagram and link to task that been saving on NI-DAQmx before as shown on Figure 3.38.

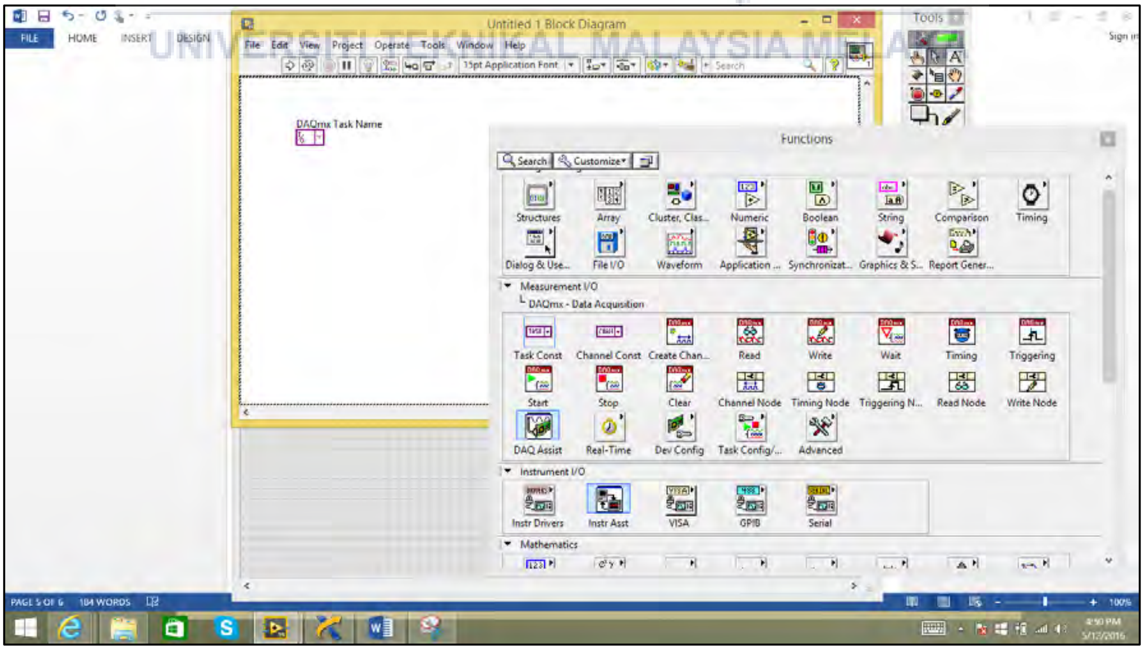


Figure 3.37: Selecting Task Control and Drag

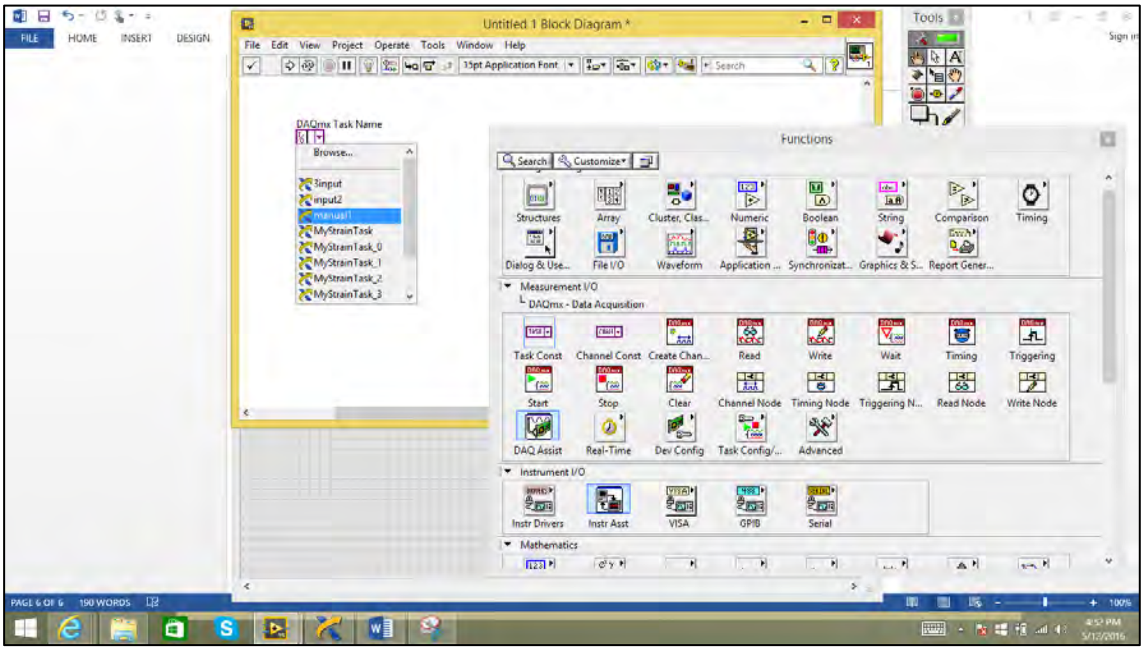


Figure 3.38: Link labview with NI-DAQmx

6) Continue by selecting DAQmx task name and convert into express VI as shown on Figure 3.39. A window will pop up to ensure data listed correctly. Then, block diagram immediately starts to build automatically as shown in Figure 3.40.

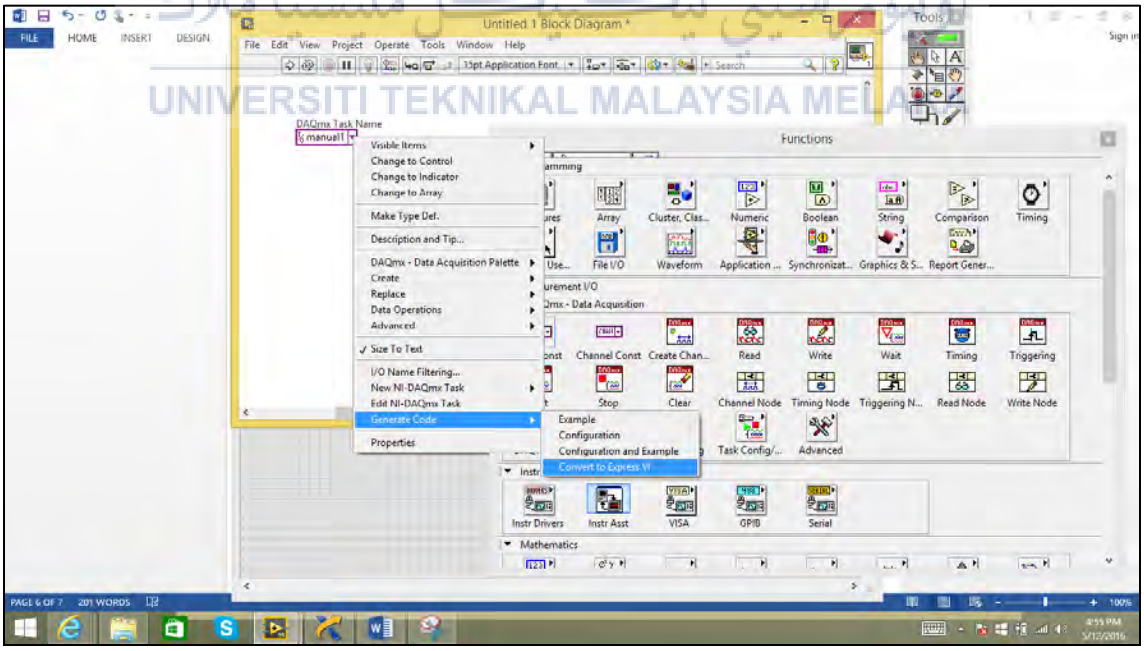


Figure 3.39: Converting to express VI

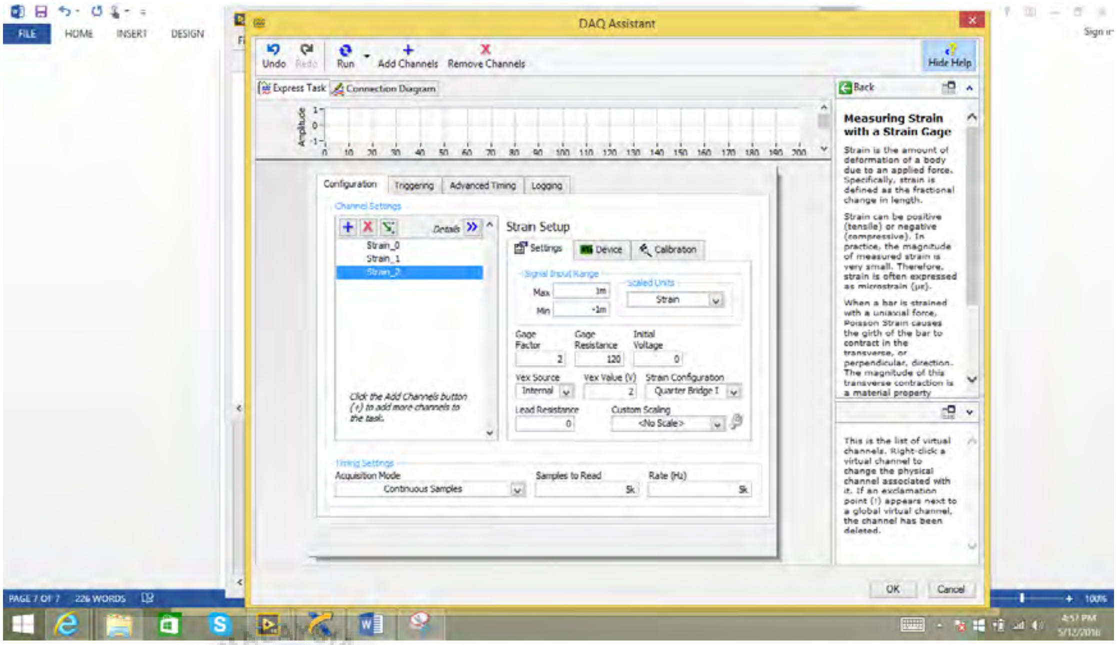


Figure 3.40: Conformation of Data

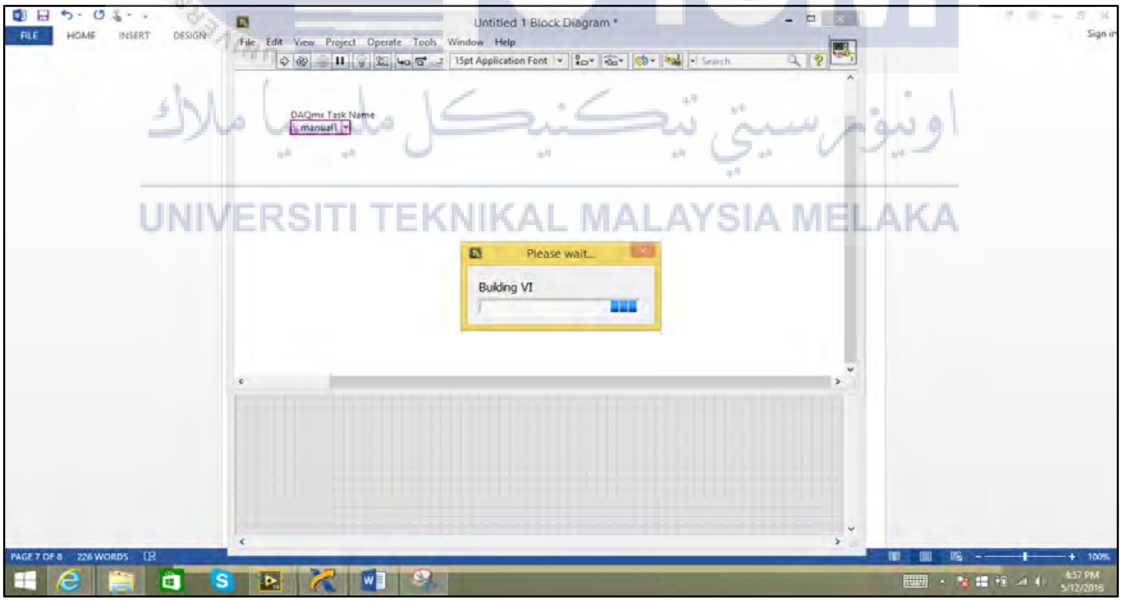


Figure 3.41: Building VI

7) New palette need to be made as a function to save the data input which is “write to measurement file”. To obtain this palette, select “programming” and proceed by select “File I/O” as shown on Figure 3.42. Palette “write to measurement file” must be dragged to block diagram. In palette “write to measurement”, data obtain can be saved in binary, excel or text as shown on Figure 3.43. Palette “write to measurement file” need to be connect with palette “Express VI” by link the data from “express VI” to signal in palette “Write to Measurement file” as shown on Figure 3.44.

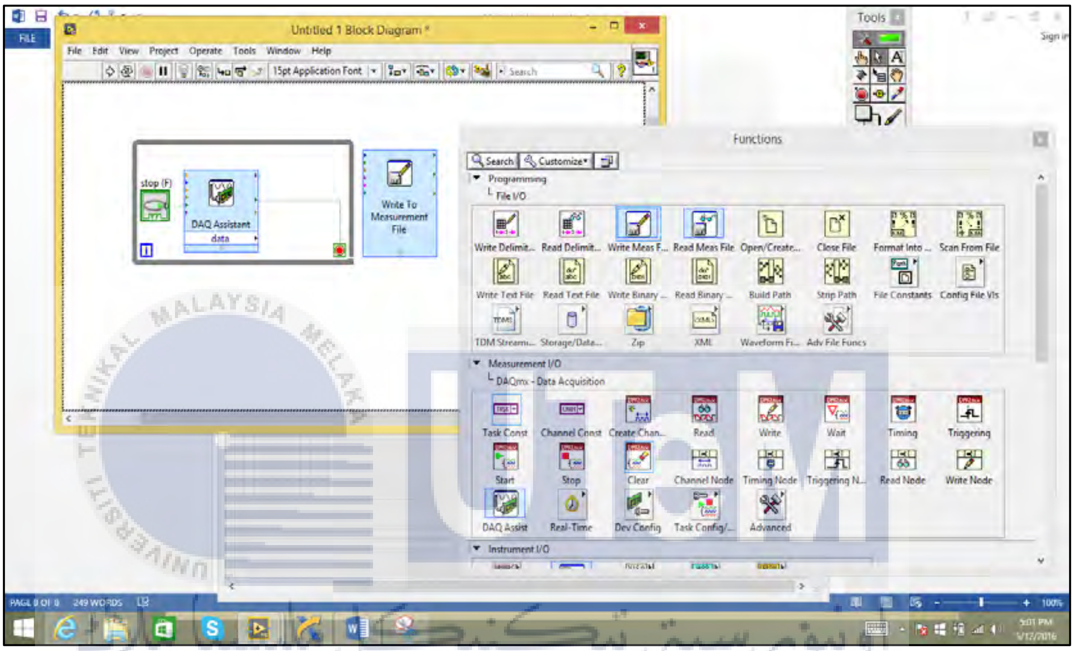


Figure 3.42: “Write to measurement file”

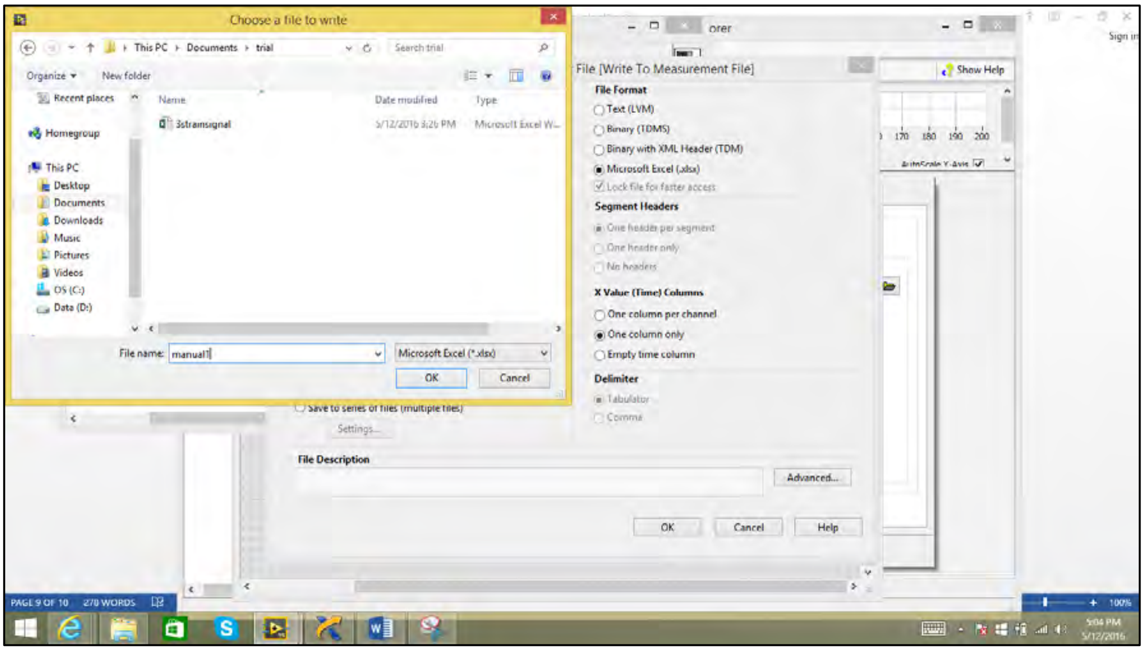


Figure 3.43: Saving file

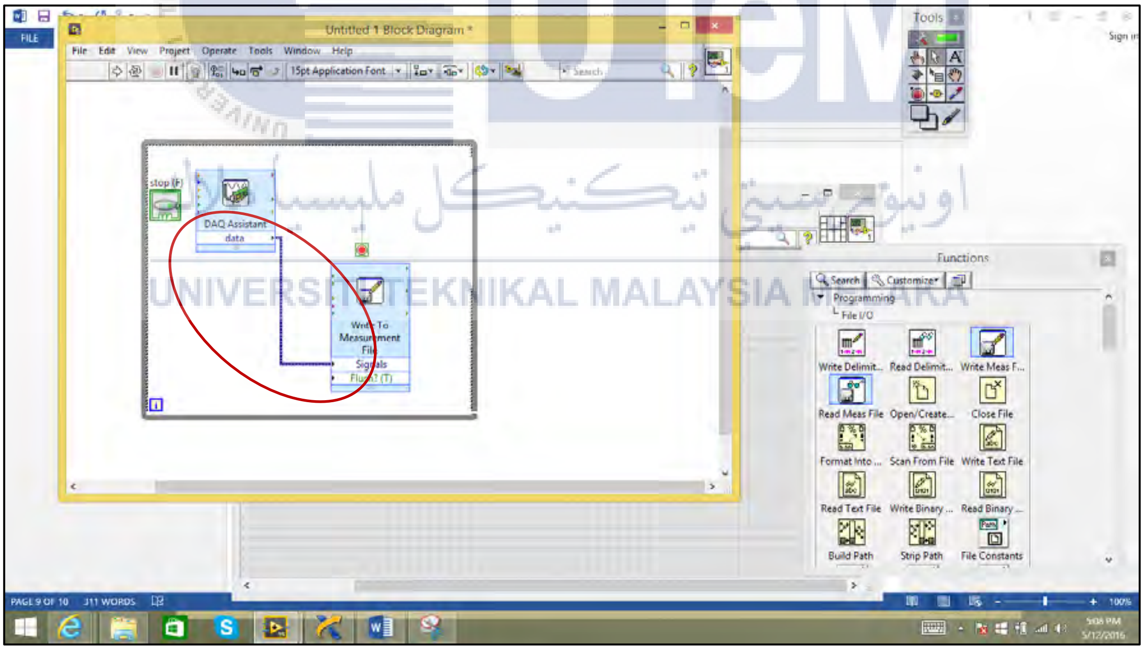


Figure 3.44: Link palette “Write to measurement file”

8) Pop up window will appear after palette link together as shown on Figure 3.45 and in front panel will produce table of graph which is amplitude versus time as shown on Figure 3.45. In order to get better result on x-value and y-value, the table of graph can be formatting as shown on Figure 3.46. The amplitude can obviously be see in the front panels as shown on Figure 3.47.

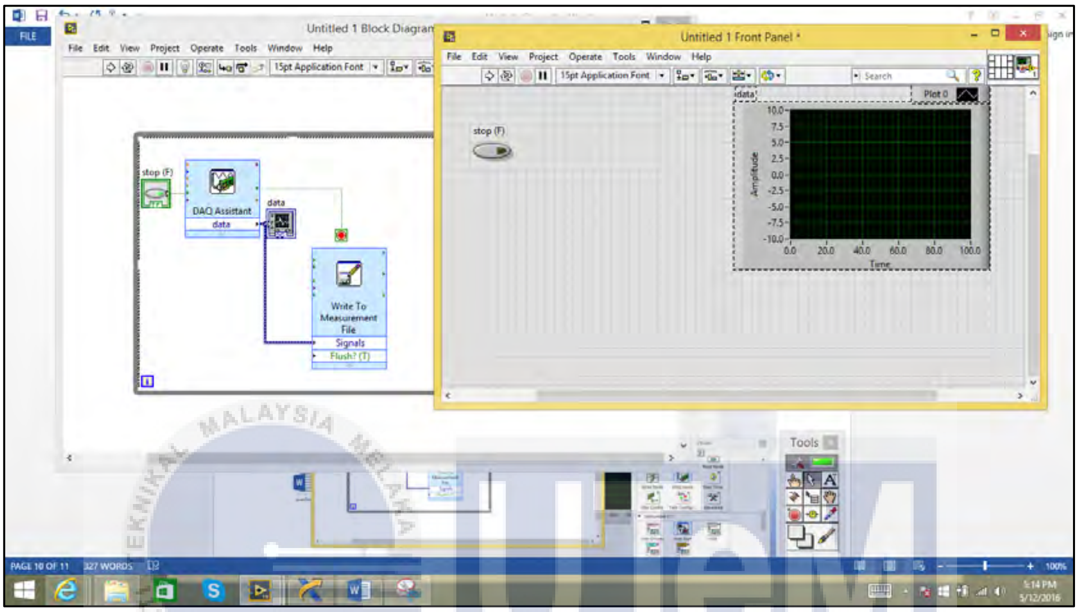


Figure 3.45: Front Panel

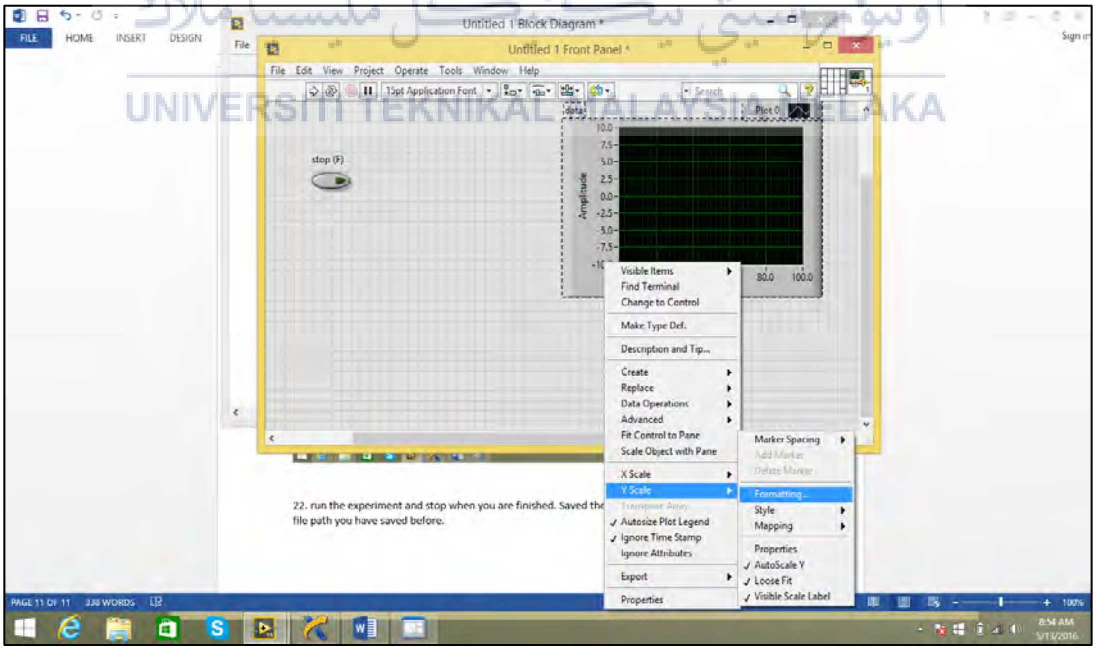


Figure 3.46: Formatting X-value and Y-value

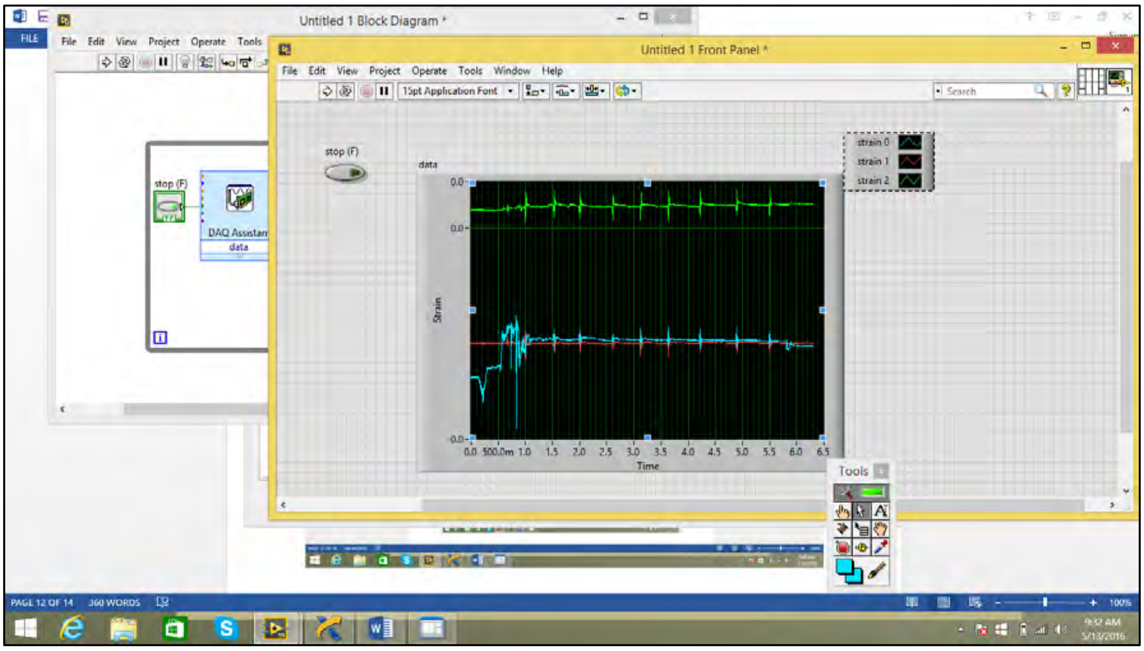


Figure 3.47: Amplitude on front panel

3.10 Type of road

In this project, the experiment will undergo by go through the two different road profile which are residential area highway area and rural area. The strain gauge that had been place on the spring absorber will come out with the signal and roads characteristic can be obtained. The way to obtain the proper result, the automobile must be moving with constant speed in a period. For residential area, the speed is 20km/h. Residential area with speed 80km/h while rural with 20km/h. Before start the experiment, the Labview software must be setup immediately as shown on Figure 3.48. The calibration step also need to be done when the car is ready to move to avoid any error. The alert sign must be put on the car for more safety as shown on Figure 3.49.

Figure 3.48: Setting of data acquisition

Figure 3.49: Alert sign on car

3.10.1 Residential Area

Route for residential area is select at Taman Tasik Utama as shown on Figure 3.50. The speed is maintained at 20km/h for 5 minutes. The condition of the road is full of bump and not quite straight.

Figure 3.50: Residential road

3.10.2 Highway Area

Highway road is a common road in our country. Therefore, will be high priority to get the data. The route for highway is select from Melaka to Alor Gajah. The speed of the car is maintaining at 80km/h. The path surface is smoother and straight compare to the residential route as shown on Figure 3.51.

Figure 3.51: Highway road

3.9 Design life (nCode software)

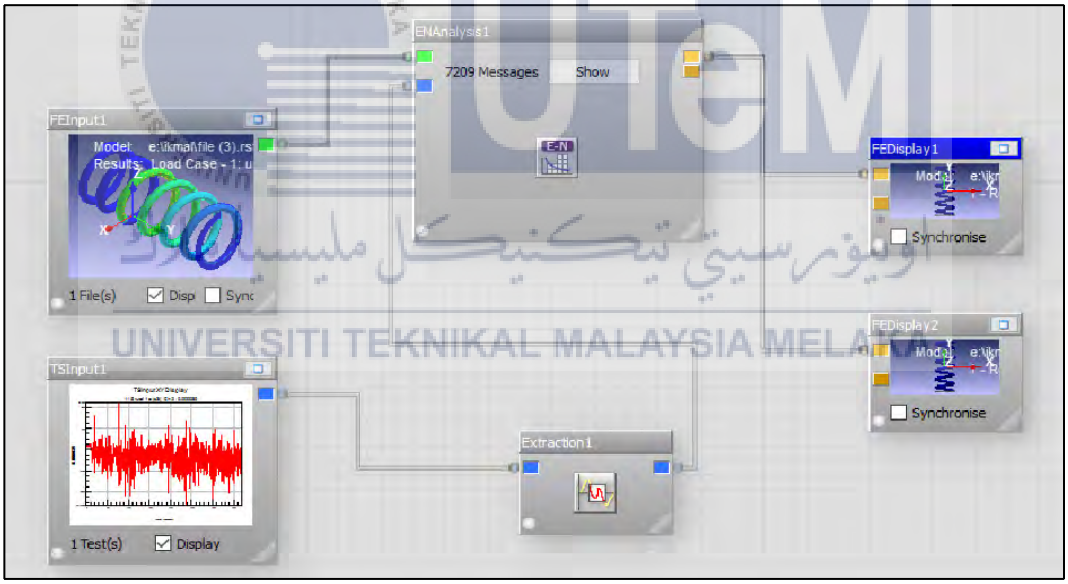


Figure 3.52: Design life layout

In design life, the software that been use is nCode. The result from static analysis in Ansys Workbench is been import in this software as shown on Figure 3.52. Then, the strain signal for the different type of road also been import. Select a E-N analysis as a main process. Select extraction and insert the time start and the time stop as it cut the time for only one minutes run. This is because to save the time when the result is undergoing. The result that been select is life and damage in form of colour contour. This two result will been display and the critical area clearly been seen.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This project was to investigate the fatigue life of the spring suspension in car system after being vulnerable by a repeated loading on different condition of road. Critical area of the spring suspension been identified and strain gauge has been place at the critical area on the spring. In order to obtained the signal, this experiment have been go through in two different road surface. There was only one strain gauge has been mounting at the spring suspension of the car. The strain signal was undergone by sample of 500Hz in 300 seconds.

4.2 Static Analysis

Structural analysis consists of linear and nonlinear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses of the material been identified to observe the failure.

4.2.1 Generate Mesh

In this study, this is the step that divides the complex model into small elements that become solvable in an otherwise too complex situation. Different type of meshing will produce different result. After fixed type was choose as the size function and the tetrahedron as a method the result of meshing was obtained as shown on Figure 4.1.

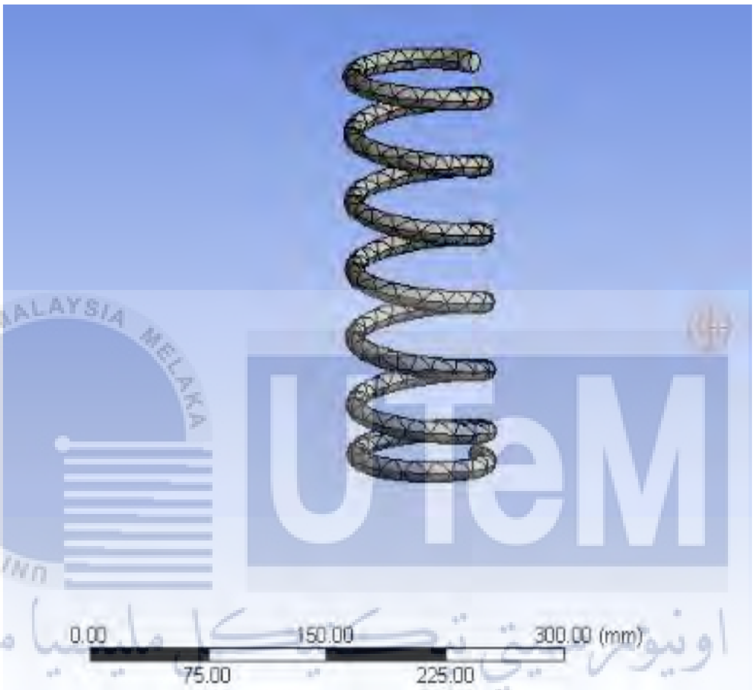


Figure 4.1: Result of meshing

In this meshing process, the perfectly meshing can be obtain by looking at the graph number of metrics Meshing process will influence to get the good result in the analysis. Selecting the right techniques of meshing are based on the geometry, model topology, analysis objectives. Tetrahedral meshing had been choosing to produce high quality meshing for boundary representation solids model. The number of element metrics was quite good due to the increasing in pattern as shown on the Figure 4.2.

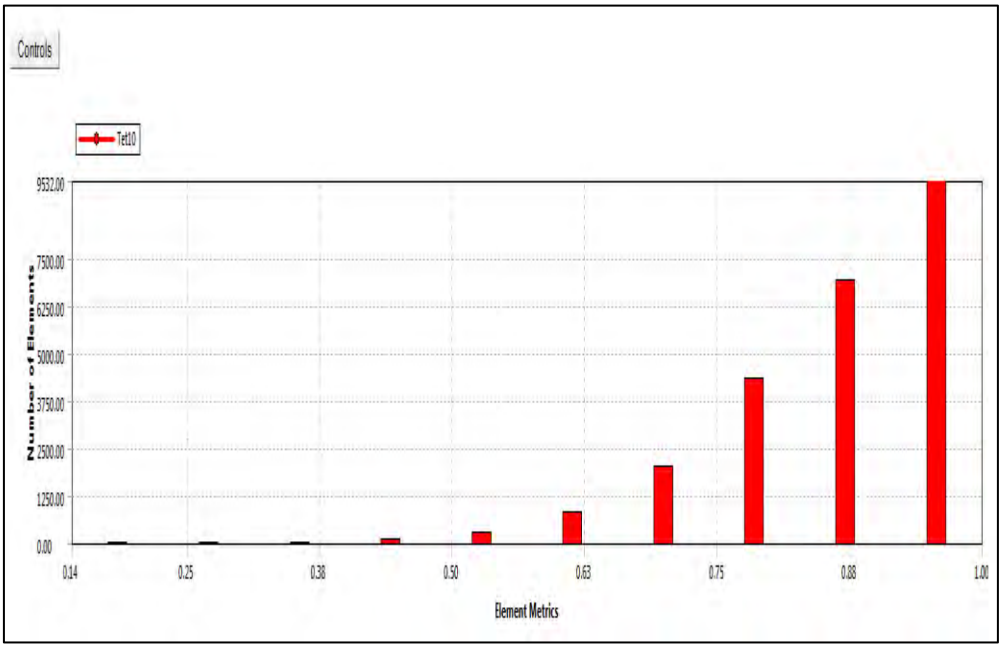


Figure 4.2: Graph number of elements metrics

After meshing, the next task was to burden the system with constraints, such as physical loadings or boundary conditions. The amount of forces that been applied in this analysis is refer to the reference of another similar journal.

Static analysis been chosen with fixed support was applied at the bottom of the spring. The force was applied at the top of the spring with value 2000N. The location where the force is projected is also important as it indicates the actual situation of the spring suspension when connected to the tyre. The analysis was done by obtained all the data and parameters involved in the analysis. In a way to represent the result, equivalent Von-Mises stress had been choosing in form of colour contour plots to identify the critical area of the spring.

4.2.2 Von-Mises stress

Figure 4.3 Result of Von-Mises stress

From the analysis result, can be seen that the stress and strain increase as the force increase. The max Von-Mises stress is 535.96MPa which is below the ultimate tensile strength of the existing material. The critical area was obtained at the inside coil of the spring with skewed to red colour as shown on Figure 4.3. It clearly indicates that failure will occur at the middle of the spring suspension. However, the safety of factor decreases as the force increase and obviously show that the spring tends to have higher percentage of failure. The use of stainless steel material because it one of the most material that been used in manufactured of spring suspension.

4.3 Strain signal

The strain signal was obtained through data collection of two different road surface. The signal consists of measurement of cyclic loading which is strain against time. The behaviour of the signal strain can clearly be it experienced the fatigue cycle loading.

4.3.1 Residential road

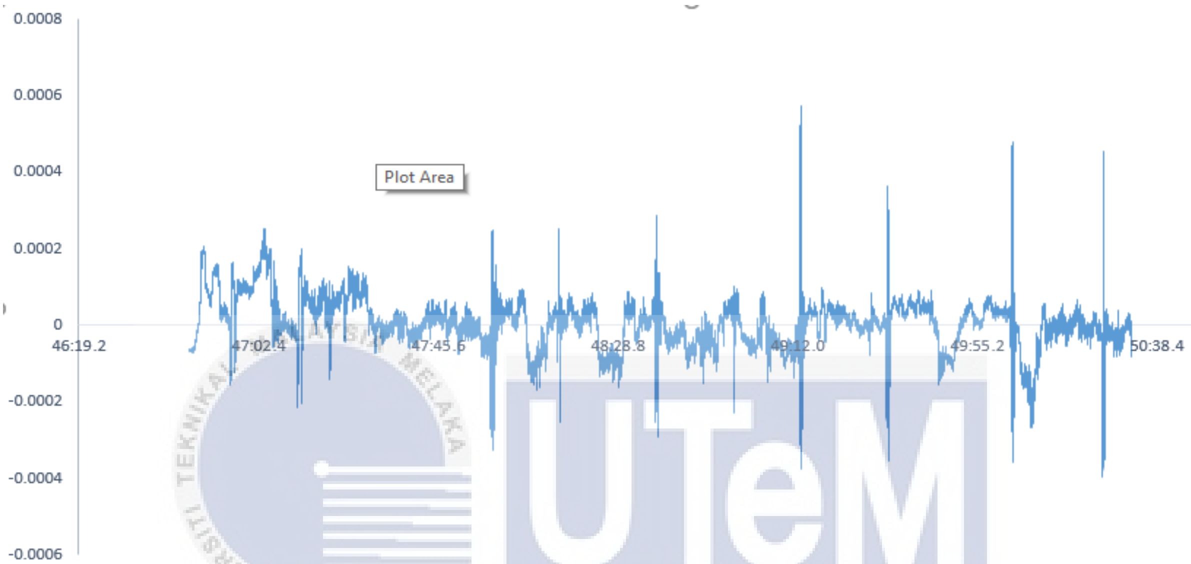


Figure 4.4: Graph on Residential road

4.3.2 Highway road

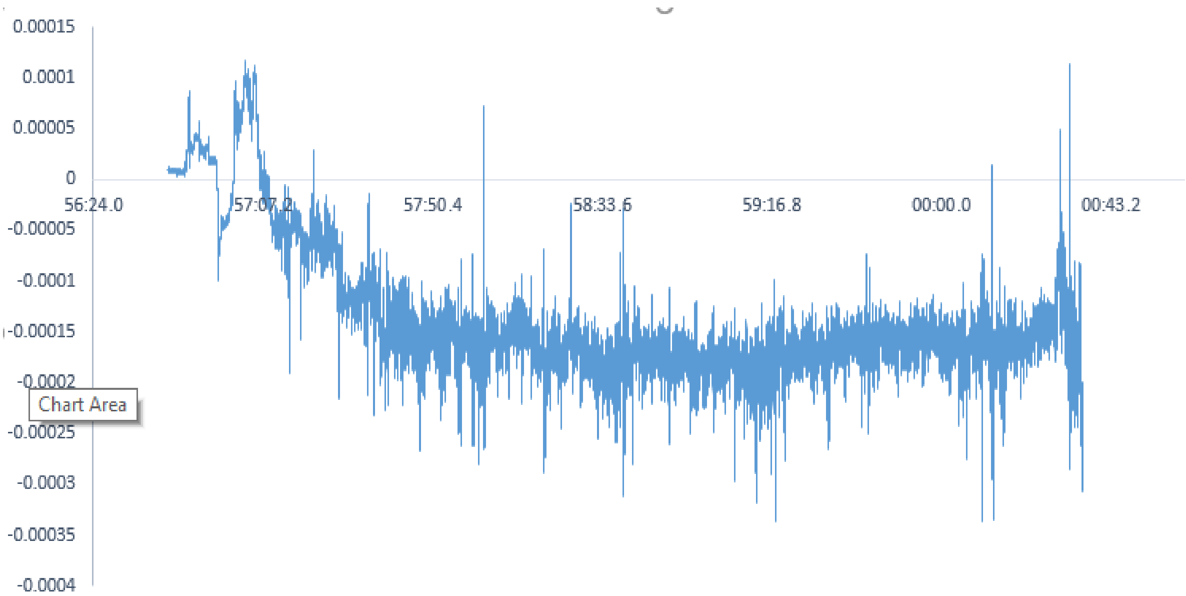


Figure 4.5: Graph on highway road

Road surface	Max	Min	Mean	Kurtosis	Standard Deviation(με)	r.m.s(με)
Residential	0.000574	-0.000398	4.72	4.941	72.56	39.04
Highway	0.000117	-0.000337	-134.945	1.6402	69.23	19.86

Table 4.1: Characteristics value of strain signals

The amplitude strain signals were sampled at 500Hz.The data show that the maximum and minimum strain value for the residential road signal were 0.000574 με. and 0.000117 με. respectively compared to the value of highway road surface at 0.000117 με. and -0.000337 με., respectively. From Figure 4.4 and Figure 4.5, it clearly shows the strain signal of highway road surface fluctuated more steadily where the strain signal of residential road surface fluctuated more frequently. The higher strain signal mean of residential road show that the spring suspension undergo a rapidly compression and tension displacement when the automobile was driven at the residential area compared to highway road surface. The presence of holes and road bumps at residential area produce high peak in amplitude of strain signal and cause the automobile to be moving more frequent.

Table 4.1 show the characteristics of the residential and highway area road strain signals. The result indicates the strain signal mean value of residential road is 4.72 με while for the highway road is -134.945 με. The standard deviation of 72.56 με and r.m.s value of 39.04 for residential road while for the highway road the standard deviation of 69.23 με and r.m.s of 19.86. From this data obtained, clearly been seen that the standard deviation and r.m.s values were higher at the residential area compared to highway area which show the strain signals were scattered more with higher amplitude.

Kurtosis is a statistical measure that's used to describe the distribution, or skewness of observed data around the mean and sometimes referred as the volatility. The residential area road strain signal showed a higher kurtosis compared with the highway road strain signal with value of 4.941 and 1.6402.

4.4 Design life

In this study, static and fatigue analysis has related each other. Static is the failure of an object when load is applied on the components. The failure can be obtained by the result of stress, strain and safety of factor. All this information will be gaining to identify the failure of the components. Meanwhile, the fatigue analysis is defined as the failure of the product after experienced the cyclic loading. Fatigue analysis by using nCode software give the accurate lifetime of the product when load and strain signal were applied.

For the fatigue analysis, by import all the data from static analysis, result can be obtained. The material used is the same but instead of normal properties, fatigue requires the E-N curve data. E-N data that have been get from the strain signal by placing the strain gauge at the spring. Then, applied the multiple signal of 30000 as it defaults setting for the analysis. Besides that, setting no interaction and select only one minutes of the time series in E-N curve. Select only one minutes is because to avoid too many data when the result been process. Result of the fatigue analysis are divided into two parts which are the damage value and life cycle value in form of colour contour. By obtaining the life and damage, the product can be analysis clearly and can be improve for further usage.

4.4.1. Residential road life and damage

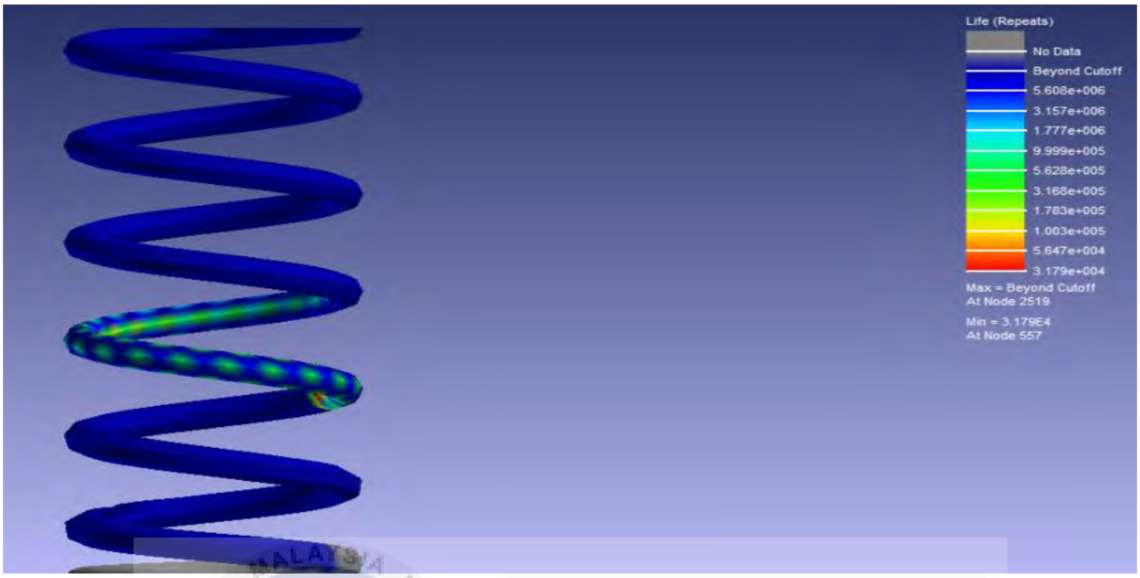


Figure 4.6: Residential Life cycles plot of spring

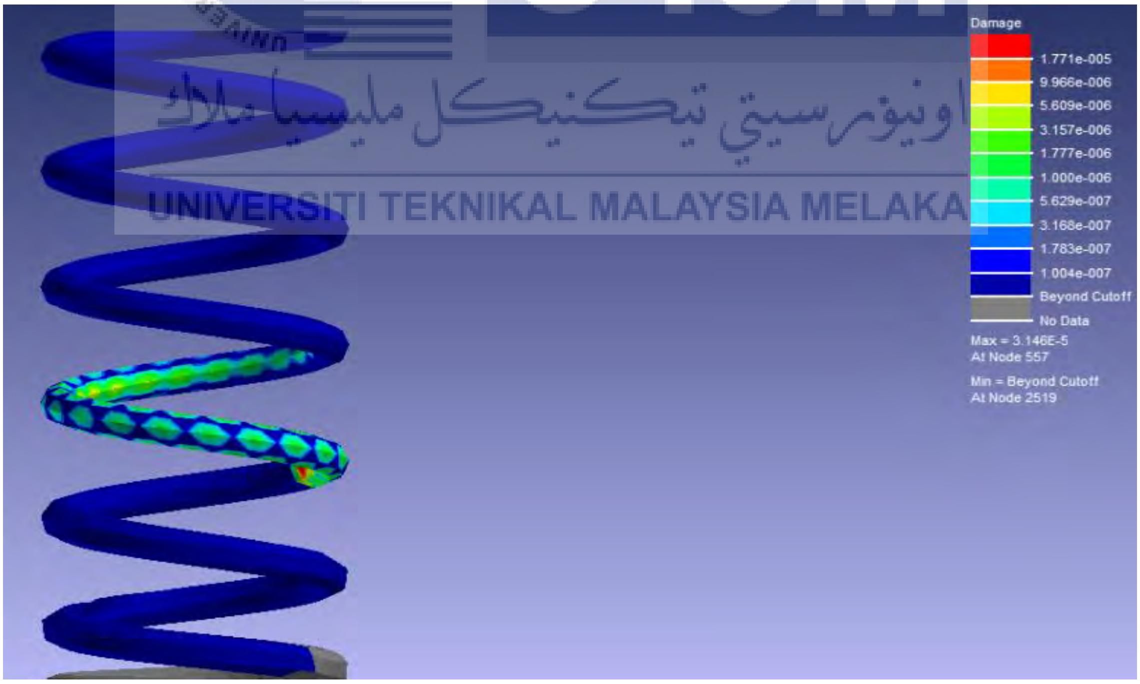


Figure 4.7: Residential damage plot of spring

4.4.2 Highway road

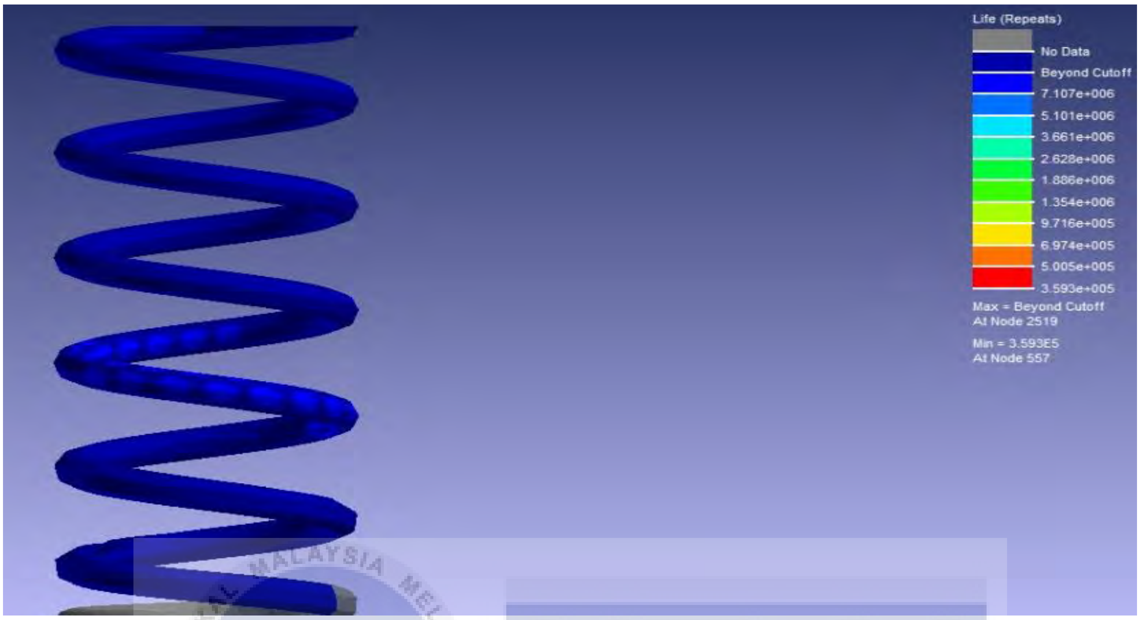


Figure 4.8: Highway Life cycles plot of spring

Figure 4.9: Highway damage plot of spring

Road surface	Fatigue Life	Fatigue Damage
Residential	3.179x10^4	3.146x10^-6
Highway	3.593x10^5	2.783x10^-6.

Table 4.2: Result of fatigue life and damage

In order to get the fatigue life prediction, nCode was widely used in the industries to calculate the fatigue life of the components. Figure 4.6 and Figure 4.8 shows the life cycle of spring suspension with the minimum value is 3.179x10^4 for residential road while the minimum value of 3.593x10^5 for highway road. This clearly indicates that the life cycle of spring at residential road is shorter than highway road. The shorter life cycle at residential area due to the road profile and the characteristic which were rougher in surface and more bump obtain. This clearly indicates that when the automobile goes through the residential road surface very often, the spring suspension will easier to achieve failure in short time.

Figure 4.7 and Figure 4.9 show the value of damage at the spring suspension once the static analysis and strain signal been plugin in this nCode software. The fatigue damage value for residential is 3.146x10^-6 which higher compared to highway road which is 2.783x10^-6. From the result, the most critical area is at the centre of inside coil. The result showed clearly that the spring experienced greater movement due to the higher magnitude of displacement or elongation when the automobile was driven over the residential area. The highway road is smooth surface condition while the residential road surface was slightly rough with small pit holes and bumps that cause the damage was high at residential. The spring suspension have a higher value of damage and easy to failure when go through residential road surface compared to highway road surface. Damage and life are related as the damage increase, life will be decrease.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As a conclusion, the spring suspension was undergoing the analysed of static and fatigue. The spring suspension was drawn using Solid Work and then been imported into design life software which is nCode. The static analysis result gives out the amount of stress and the critical area of the spring suspension. The strain signals of the spring suspension that had been analysis by statistical method clearly influence by the road surface respectively. Statistical and strain signal behaviour such as maximum, minimum, mean, kurtosis and standard deviation clearly indicates higher for residential road compared to highway road.

The spring suspension is one of the crucial components in a car that must have a higher endurance when go through all road surface conditions. For damage and life cycle, it was inversely proportional. As the high damage occur, the life cycle will decrease. The damage value for the spring suspension at residential area is higher compared to the highway road. Therefore, the life cycle at residential area is less than highway road. The life span of the spring suspension was significantly depending on the road surface that automobile was driven through. The information of static analysis, strain signals behaviour and fatigue analysis were obviously influence in getting the fatigue life prediction of the spring suspension.

5.2 RECOMMENDATION

As a recommendation, the drawing of the spring suspension need to be more accurate and significant to the actual product. The tolerances should not be too higher to obtain the good result. Besides that, the strain gauge need to install properly at the spring to easily identified the signal behaviour. The material of the strain gauge also must have a higher resistance towards all the external and internal effects to gain the accurate result. The comparison between materials of spring suspension also can be done as it helps to give more understanding. In addition, the type of road surface can be added more to get the variety of data and can obtain better results.

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APPENDICES

GANTT CHART FOR PSM 1

Period Highlight: 0

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION
PROJECT INTRODUCTION	1	5	1	5
FYP Discussions with SV	1	3	1	3
Problem Statement	2	2	2	2
objectives	4	2	4	2
scope	4	2	4	2
GANTT CHART	2	4	2	4
Action Plan	2	3	2	3
Content Strategy	2	1	2	1
Research Plan	3	3	3	3
SV meeting	2	4	2	4
LITERATURE SURVEYING	1	8	1	8
Suspension system	3	5	3	5
Statistical analysis	5	4	5	4
Fatigue life	5	4	5	4
DETERMINATION OF CRITICAL A	6	8	6	8
SolidWork drawing	6	8	6	8
PROGRESS REPORT	2	7	2	7
Proposal	7	8	7	8
Report Writing	9	6	9	6
SUBMIT REPORT	14	1	14	1

WEEK: 1 2 3 4 5 6 7 8 9 10 11 12 13 14

GANTT CHART FOR PSM 2

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION
Simulation using FEA analysis	1	3	1	3
Obtained the strain signal	3	3	3	3
Simulation using Design life software	6	5	6	5
Writing final report	6	9	6	9
Submission progress report	7	1	7	1
Submission final report	14	14	14	14

WEEK: 1 2 3 4 5 6 7 8 9 10 11 12 13 14