A STUDY OF THE CAUSES OF BOUNCING PROBLEMS OF SHOCK ABSORBER

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SESI PENGAJIAN: **2011/2012**

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A STUDY OF THE CAUSES OF BOUNCING PROBLEMS OF SHOCK ABSORBER

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A thesis submitted in partial fulfillment of the requirement
for the award of the degree of
Bachelor of Manufacturing Engineering

Faculty of Manufacturing Engineering
Universiti Malaysia Pahang

JUNE 2012

UNIVERSITI MALAYSIA PAHANG
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We certify that the projects entitle A Study of The Causes of Bouncing Problems of Shock Absorber is written by Mohd Sufian Bin Jamaludin. We have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of degree of Bachelor of Engineering. We herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering.

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DEDICATION

To my beloved parents, Mr. Jamaludin Bin Jumahat and Mrs. Shamsiah Binti Abdollah, family and friends, without whom and his/her lifetime efforts, my pursuit of higher education would not have been possible and I would not have had the chance to study for a manufacturing course. Also to my supervisor, Mrs. Munira Binti Mohd Ali, because of the guidance without whose wise suggestions, helpful guidance and direct assistance, it could have neither got off the ground nor ever been completed.

ACKNOWLEDGEMENTS

The author would like to express the heartiest gratitude to author's supervisor Mrs. Munira Binti Mohd Ali for her patient guidance and continuous encouragement which significantly helped me to finish this project successfully. The author appreciates her consistent support throughout the progress of the project and her tolerance to my naïve mistakes. Endless thank you go to all the staffs of Faculty of Manufacturing Engineering and fellow friends in UMP who have always been rendering the author assistance and make her stay in UMP pleasant and unforgettable. The author acknowledges his sincere indebtedness and gratitude to his parents for their sacrifices and encouragement to give the author such a precious to continue his higher education in UMP. Again, special thanks to all who had been such crucial roles for the successful completion of this study.

ABSTRACT

The purpose of the project is to investigate the problems of shock absorber in the market. The shock absorber is commonly use at all vehicle today. There are some problem happen at the vehicle when ride at the bumping road condition. One of the problems is that the vehicle bounce continuously more than one times and it is called as bouncing problems. The objective of this project is to study the causes of the bouncing problem at the vehicle and to compare the failure parts performance in terms of its yield strength between steel and beryllium copper. The scope of study for this project includes, experimental of suspension systems and bouncing problem in vehicle, apply structural analysis and model analysis on the shock absorber and application of Finite Element Analysis (FEA). In this project, after make an experiment and analysis, the problem of bouncing problem of shock absorber is come from the spring. Overall, this project acquires the skills of using software and skills to investigate the problem.

ABSTRAK

Tujuan utama projek adalah untuk menyiasat masalah penyerap hentakan di pasaran sekarang. Penyerap hentakan banyak digunakan di semua kenderaan pada hari ini. Terdapat beberapa masalah yang berlaku pada kenderaan apabila memandu di jalan yang tidak rata. Masalah utama ialah lantunan. Objektif projek ini adalah untuk mengkaji punca-punca masalah lantunan pada kenderaan dan membandingkan bahan pada bahagian yang paling cepat mengalami kegagalan menggunakan CATIA bagi mengurangkan masalah tersebut. Skop kajian bagi projek ini termasuklah eksperimen sistem hentakan dan masalah lantunan pada kenderaan, menggunakan analisis struktur dan analisis model pada penyerap hentakan dan menggunakan “Finite Element Analysis” (FEA). Di dalam projek ini, setelah menjalankan ekperimen dan analisis, masalah lantunan pada penyerap hentakan berpunca dari spring. Secara keseluruhannya, projek ini memberikan saya kemahiran menggunakan perisian dan kemahiran untuk mengkaji masalah.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

A suspension system or shock absorber is a mechanical device designed to smooth out and dissipate kinetic energy. The shock absorbers function is to absorb or dissipate energy. In a vehicle, it reduces the effect of traveling over rough ground, leading to improve ride quality, and increase in comfort due to substantially reduced amplitude of disturbances.

Basic safety and also traveling ease and comfort to get a car's motorist are usually equally influenced by the particular vehicle's suspension method. Safety refers to the vehicle's handling and braking capabilities. Shock absorbers are a critical part of a suspension system, connecting the vehicle to its wheels. Basically shock absorbers tend to be products which lessen a good behavioral instinct skilled with an automobile, as well as properly absorb the actual kinetic power. Almost all suspension systems consist of springs and dampers, which tend to limit the performance of a system due to their physical constraints. Suspension systems, comprising of springs and dampers are usually designed for passenger's safety and do little to improve passenger comfort.

One particular strategy to this can be the application of productive suspension devices, wherever highway circumstances are generally found employing detectors, plus the technique in a flash adapts on the placing. A shock absorber is a device which is designed to smooth out sudden impulse responses, and dissipate kinetic energy. Any moving object possesses kinetic energy, and if the object changes direction or is brought to rest, it may dissipate kinetic energy in the form of destructive forces within the object. The purpose of a shock absorber, within any moving object, is to dissolve the kinetic energy evenly while eliminating any decelerating force that may be destructive to the object.

Shock absorbers are an important part of automobile and motorcycle suspensions, aircraft landing gear, and the supports for many industrial machines. Large shock absorbers have also been used in structural engineering to reduce the susceptibility of structures to earthquake damage. A transverse mounted shock absorber, helps keep railcars from swaying excessively from side to side and are important in passenger railroads systems because they prevent railcars from damaging station platforms. In a vehicle, it reduces the effect of traveling over rough ground, and leading to improved ride quality. Without shock absorbers, the vehicle would have a bouncing ride, as energy is stored in the spring and then released to the vehicle, possibly exceeding the allowed range of suspension movement.

A typical shock absorber may simply comprise of a compression spring that is capable of absorbing energy. Commonly shock absorbers are known as dashpots, which is simply a fluid filled cylinder with an aperture through which fluid could escape under controlled conditions. The dashpot is the building block for pneumatic and hydraulic shock absorbers. These shock absorbers essentially consist of a cylinder, filled with air or fluid, with a sliding piston that moves to dissipate or absorb energy, and in these cases the energy is usually dissipated as heat.

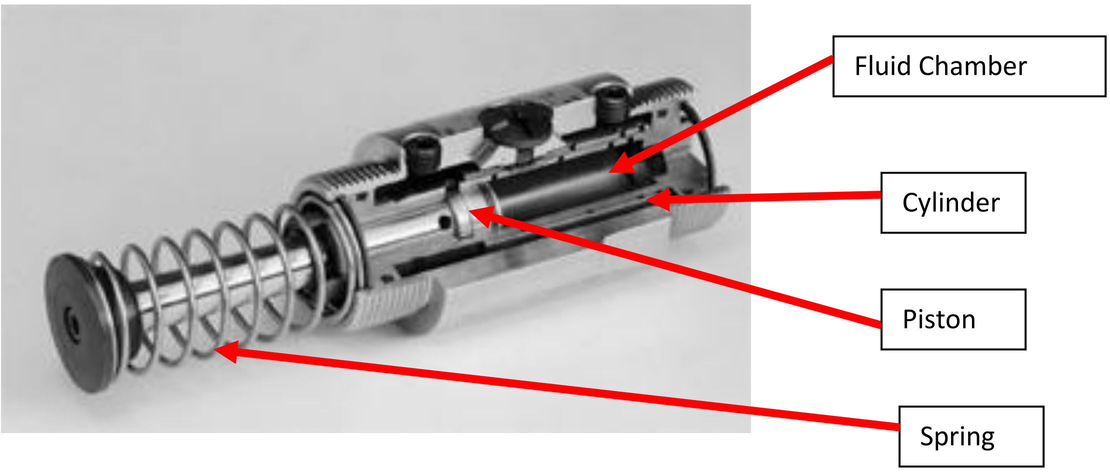


Figure 1.1: Cutaway View of Hydraulic Shock Absorber.

1.2 Problem Statement.

When a vehicle is travelling on a level road and the wheels strike a bump, the spring is compressed quickly. The compressed spring will attempt to return to its normal loaded length. It will rebound past its normal height, causing the body to be lift. The weight of the vehicle will then push the spring down below its normal load height. This causes the spring to rebound again. This bouncing process is repeated over and over, a little less each time, until the up and down movement finally stops. If bouncing is allowed to go uncontrolled, it will not only cause an uncomfortable ride but will make handling of the vehicle very difficult.

1.3 Objectives of the Project.

The objectives of the project are to:

- Study the causes of the bouncing problem at the vehicle.
- Compare the failure parts performance in terms of its yield strength between steel and beryllium copper.

1.4 Scope of Study

The scope of study for this project includes:-

- Experimental of suspension systems and bouncing problem in vehicle.
- Applying structural analysis and model analysis on the shock absorber.
- Application of Finite Element Analysis (FEA).

CHAPTER 2

LITERATURE REVIEW

2.1 Shock Absorber.

The shock absorber is really a mechanized gadget made to lessen or even moist surprise behavioral instinct, as well as dissolve kinetic power. It's a kind of dashpot. The shock absorber function is to absorb or dissipate energy. One design consideration, when designing or choosing a shock absorber, is where that energy will go. In many dashpots, power is actually transformed into warmth within the viscous liquid. Within hydraulic cylinders, the actual hydraulic liquid gets hotter, during atmosphere cylinders, the actual heat is generally worn out towards the environment. In other types of dashpots, such as electromagnetic types, the dissipated energy can be stored and used later. In general terms, shock absorbers help cushion vehicles on uneven roads.

Shock absorbers tend to be an essential a part of car as well as motorbike suspensions, plane getting equipment, and also the facilities for a lot of commercial devices. Big shock absorbers are also utilized in structural architectural to lessen the actual susceptibility associated with buildings in order to earthquake harm as well as resonance. The transverse installed shock absorber, known as the yaw damper, helps maintain railcars through swaying too much laterally and therefore are essential within traveler railroads, commuter train as well as quick transit techniques simply because they avoid railcars through harmful train station systems.

Inside a vehicle, shock absorbers slow up the effect associated with traveling more than rough floor, leading in order to improve trip quality as well as increase within comfort. While surprise absorbers serve the objective of limiting extreme suspension motion, their meant sole purpose would be to dampen springtime oscillations. Shock absorbers make use of valve associated with oil as well as gasses to soak up excess energy in the springs. Spring prices are chosen through the manufacturer in line with the weight from the vehicle, packed and unloaded. Some individuals use shocks to change spring prices but this isn't the proper use. Together with hysteresis within the tire by itself, they dampen the power stored within the motion from the unsparing weight down and up. Effective steering wheel bounce damping may need tuning shocks for an optimal opposition.

Spring-based surprise absorbers generally use coils springs or even leaf comes, though torsion bars are utilized in torsion shocks too. Ideal comes alone, nevertheless, are not really shock absorbers, as come only store and don't dissipate or even absorb power. Vehicles usually employ each hydraulic surprise absorbers as well as springs or even torsion pubs. In this particular combination, "shock absorber" pertains specifically towards the hydraulic piston which absorbs as well as dissipates vibration.

Figure 2.1: Shock Absorber in Market

2.2 Types of Shock Absorbers

There are several shock absorber designs in use today like Twin Tube Designs, Gas Charged, PSD (position sensitive damping), ASD (Acceleration Sensitive Damping) and Mono-Tube.

2.2.1 Twin Tube – Gas Charged Design

The prime function of gas charging is to minimize aeration of the hydraulic fluid. The pressure of the nitrogen gas compresses air bubbles in the hydraulic fluid. This prevents the oil and air from mixing and creating foam. Foam affects performance because it can be compressed fluid. With aeration reduced, the shock is able to react faster and more predictably, allowing for quicker response time and helping keep the tire firmly planted on the road surface.

The advantages of this shock absorber are improves handling by reducing roll, sway and dive. Also can reduces aeration offering a greater range of control over a wider variety of road conditions as compared to non-gas units. This shock absorber reduced fade shocks can lose damping capability as they heat up during use. Gas charged shocks could cut this loss of performance.

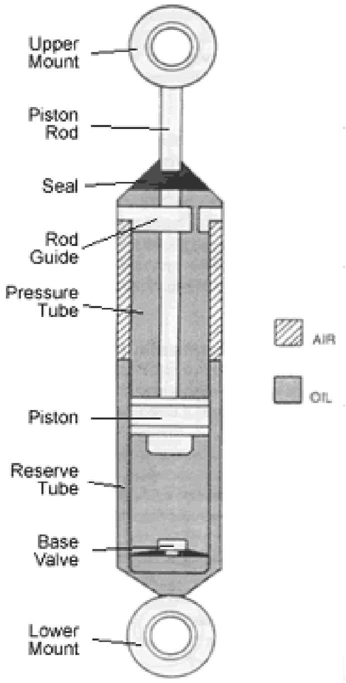


Figure 2.2: Gas Charged Design

2.2.2 Twin Tube – PSD Design

Ride engineers had to compromise between soft valve and firm valve. With soft valve, the fluid flows more easily. The result is a smoother ride, but with poor handling and a lot of roll/sway. When valve is firm, fluid flows less easily. Handling is improved, but the ride can become harsh. With the advent of gas charging, ride engineers were able to open up the orifice controls of these valves and improve the balance between comfort and control capabilities available in traditional velocity sensitive dampers. A leap beyond fluid velocity control is an advanced technology that takes into account the position of the valve within the pressure tube. This is called Position Sensitive Damping (PSD).

The key to this innovation is precision tapered grooves in the pressure tube. Every application is individually tuned, tailoring the length, depth, and taper of these grooves to ensure optimal ride comfort and added control. This in essence creates two zones within the pressure tube. The first zone, the comfort zone, is where normal driving takes place. The second zone, the control zone, is utilized during demanding driving situations.

The advantages is allows ride engineers to move beyond simple velocity sensitive valve and use the position of the piston to fine tune the ride characteristic. Adjusts more rapidly to changing road and weight conditions than standard shock absorbers.

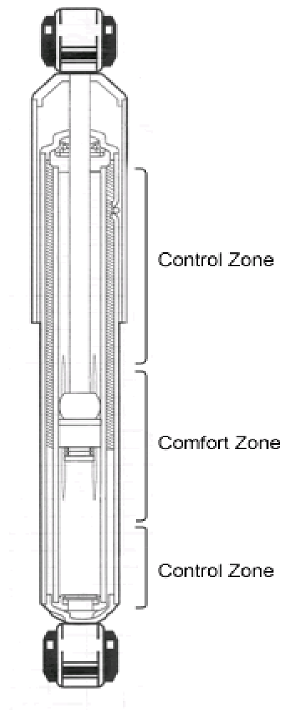


Figure 2.3: Twin Tube – PSD Design

2.2.3 Twin Tube -ASD Design (Reflex)

A new twist on the comfort control compromise is an innovative technology which provides greater control for handling while improving ride comfort called Acceleration Sensitive Damping (ASD). This technology moves beyond traditional velocity sensitive damping to focus and address impact. This focus on impact is achieved by utilizing a new compression valve design. This compression valve is a mechanical closed loop system, which opens a bypass to fluid flow around the compression valve.

The advantage of this absorber is it can control the damping without reducing driver comfort. Valve automatically adjusts to changes in the road condition and reduces ride harshness.

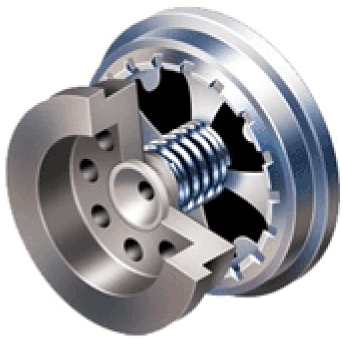


Figure 2.4: Twin Tube -ASD Design (Reflex)

2.2.4 Mono-tube design (Standard Types)

These are high-pressure gas shocks with only one tube, the pressure tube. Inside the pressure tube there are two pistons: a dividing piston and a working piston. The working piston and rod are very similar to the twin tube shock design. The difference in actual application is that a mono-tube shock absorber can be mounted upside down or right side up and will work either way. In addition to its mounting flexibility, mono-tube shocks are a significant component, along with the spring, in supporting vehicle weight. Another difference you may notice is that the mono-tube shock absorber does not have a base valve. Instead, all of the control during compression and extension takes place at the piston. During operation, the dividing piston moves up and down as the piston rod moves in and out of the shock absorber, keeping the pressure tube full all times.

The advantages for this absorber is that it can be mounted upside down, reducing the unsparing weight. May run cooler since the working tube is exposed to the air and can use original equipment many import and performance domestic passenger cars, SUV and light truck applications

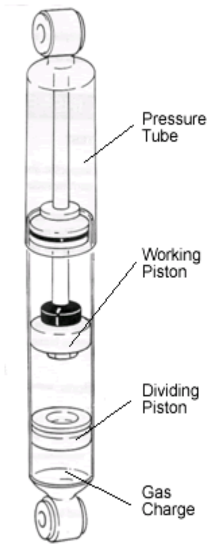


Figure 2.5: Mono-tube design (Standard Types)

2.3 Main Component of Shock Absorber.

Shock absorber has three main components to make it function well. There are damper, spring and bushing. These all three part is playing an important rule to work together and absorb the impact or bouncing.

2.3.1 Damper.

Damper shock absorber or simply damper is device that is designed for providing absorption of shock and smooth deceleration in linear motion applications. The dampers can be either mechanical or rely on a fluid. Dampers like other shock absorber absorb shock by controlling the flow of the fluid from outer to inner chamber of a cylinder during piston actuation. The damper shock absorbers can be adjusted to different road conditions and provides good balance to the vehicles.

2.3.2 Spring.

Spring shock absorber as the name suggests is used to absorb the jerks or bumps by using coil spring. The spring shock absorber is given stiffer character by tightening the spring. The center of the spring shock absorber usually contains rebound dampening unit. As the shock absorber changes the length the flow fluid inside the shock absorber starts.

Springs length is usually controlled by turning the disc at the bottom of the spring on the threads. The shorter spring length increases the preload, making the rear wheel more resistant to upward motion. The dampening is both controlled and adjusted in the spring shock absorber by controlling the fluid reservoir. If the dampening is increased the motion of the shock is slowed down.

The spring type of shock absorbers are usually utilized for protecting the delicate mechanisms, like instruments, from direct impact or or loads that are applied instantaneously. These types of springs are often made of rubber or similar elastic material.

The springs that are used in different spring based shock absorbers are coil springs or leaf springs. In tensional shocks, torsion bars can be used. In most of the vehicles, springs or torsion bars as well as hydraulic shock absorbers are used.

2.3.3 Bushing.

A bushing or rubber bushing is a type of vibration isolator. It provides an interface between two parts, damping the energy transmitted through the bushing. A common application is in vehicle suspension systems, where a bushing made of rubber (or, more often, synthetic rubber or polyurethane) separates the faces of two metal objects while allowing a certain amount of movement. This movement allows the suspension parts to move freely, for example, when traveling over a large bump, while minimizing transmission of noise and small vibrations through to the chassis of the vehicle. A rubber bushing may also be described as a flexible mounting or anti vibration mounting.

2.4 Design Calculations for Helical springs for Shock absorbers

Material: phosphorous bronze

G = 41000 = modulus of rigidity

Mean diameter of a coil = D=62mm

Diameter of wire d = 8mm

Total no of coils n_1 = 18

Height h = 220mm

Outer diameter of spring coil D_0 = D +d =70mm

No of active turns n = 14

Weight of bike = 125kgs

Let weight of 1 person = 75 Kgs

Weight of 2 persons = $75\times 2 = 150Kgs$

Weight of bike + persons = 275Kgs

Rear suspension = 65%

65% of 275 = 165Kgs

Considering dynamic loads it will be double

W = 330Kgs = 3234N

For single shock absorber weight = w/2= 1617N = W

We Know that, compression of spring (δ) = $\frac{8W\times C^3\times n}{G\times d}$

$$C = \text{spring index} = \frac{D}{d} = \frac{62}{8} = 7.75 = 8$$

$$(\delta) = \frac{8\times 1617\times 8^3\times 14}{41000\times 8} = 282.698m$$

Solid length = $L_s = n^1 \times d = 18 \times 8 = 144$

Free length of the spring $L_F = solid\ length + maximum\ compression + clearences\ between\ adjustible\ coils$

$$= n^1 d + \delta_{max} + 0.15\delta_{max} = 144 + 282.698 + 0.15 \times 282.698 = 469.102$$

Spring rate K = $\frac{W}{\delta} = \frac{1617}{282.698} = 5.719$

Pitch of coil P = $\frac{L_F + L_S}{n^1} = \frac{469.102 - 144}{18} = 26$

Stresses in helical springs: maximum shear stress induced in the wire

$$\tau = K \times \frac{8WC}{\pi d^2}$$

$$K = \frac{4_C - 1}{4_c - 4} + \frac{0.615}{C} = \frac{4 \times 8 - 1}{4 \times 8 - 4} + \frac{0.615}{8} = 0.97$$

$$\tau = K \times \frac{8WC}{\pi d^2} = 0.97 \times \frac{8 \times 1617 \times 8}{\pi \times 8^2} = 499.519 Mpa$$

Buckling of compression springs:

$$W_{cr} = k \times K_B \times L_F$$

K = spring rate or stiffness of spring = $\frac{W}{\delta}$

$L_F = free\ length\ of\ the\ springs$

$K_B = buckling\ factor\ depending\ upon\ the\ ratio = \frac{L_F}{D}$

Values of buckling factor K_B

$$\frac{L_F}{D} = \frac{469.102}{62} = 7.5$$

K = 0.05 (for hinged and spring)

The buckling factor for the hinged end and built-in end springs

$$W_{cr} = 5.719 \times 0.05 \times 469.102 = 134.139N$$

[Reference from the Simulation Tools, Modeling and Identification, for an Automotive Shock Absorber in the Context of Vehicle Dynamics.]

2.5 CATIA V5

CATIA-V5 is the industry standard 3D mechanical design software. It is the world's leading CAD/CAM/CAE software, gives a broad range of integrated solutions to cover all aspects of product design and manufacturing. Much of its success can be attributed to its technology which spurs its customers to more quickly and consistently innovate a new robust, parametric feature based model. Because of that CATIA V5 is unmatched in this field, in all processes, in all countries, and in all kind of companies along the supply chains. CATIA V5 is also the perfect solution for the manufacturing enterprise with associative applications robust responsiveness and web connectivity that make it the ideal flexible engineering solution to accelerate innovations.

CATIA V5 provides easy to use solution tailored to the needs of small medium sized enterprises as well as large industrial corporations in all industries consumer goods, fabrications and assembly. Electrical and electronics goods, automotive, aerospace, shipbuilding and plant design. It is user friendly solid and surface modeling can be done easily.

Advantages of CATIA-V5 are it is much faster and more accurate. Once a design is completed 2D and 3D views are readily obtainable. The ability to changes in late design process is possible. It provides a very accurate representation of model specifying all other dimensions hidden geometry. It is user friendly both solid and surface modeling can be done. It provides a greater flexibility for change. For example if we like to change the dimensions of our model, all the related dimensions in design assembly manufacturing will automatically change. It provides clear 3D models, which are easy to visualize and understand. CATIA provides easy assembly of the individual parts or models created it also decreases the time required for the assembly to a large extent.

A solid model of an object is a completed representation of the object. This model is capable of complex geometry data representation that is the art completely defined solid modeling techniques based on information all complete, valid and unambiguous of object solid modelers store more information (geometry and topology) than wire frame modelers of surface (geometry only). Both wire frame and surface modelers are incapable of handling special address ability as well as verifying that the model is well framed or not. Solid models can be quickly created without having to define individual locations as with wire frames. Solid modeling produces accurate designs, provides complete three-dimensional improves the quality of the design improves and has potential for functional automation and integration.

2.6 Finite Element Analysis (FEA).

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures".

By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters.

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the clients specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in industry. That is 2D modeling and 3D modeling. While 2D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3D modeling however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object creating many elements.

A wide range of objective functions (variables within the system) are available for minimization or maximization:

- Mass, volume, temperature.
- Strain energy, stress strain.
- Force, displacement, velocity, acceleration.
- Synthetic.

There are multiple loading conditions which may be applied to a system. Some examples are shown:

- Point, pressure, thermal, gravity, and centrifugal static loads.
- Thermal loads from solution of heat transfer analysis.
- Enforced displacements.
- Heat flux and convection.
- Point, pressure and gravity dynamic loads.

Each FEA program may come with an element library, or one is constructed over time. Some sample elements are:

- Rod elements.
- Beam elements.
- Plate, Shell, Composite elements.
- Shear panel.
- Solid elements.
- Spring elements.
- Mass elements.
- Rigid elements.
- Viscous damping elements.

Many FEA programs also are equipped with the capability to use multiple materials within the structure such as:

- Isotropic, identical throughout.
- Orthotropic, identical at 90 degrees.
- General anisotropic, different throughout.

2.7 Types of Engineering Analysis

There are some types of engineering analysis that can be use. They are structural analysis, vibration analysis, fatigue analysis and heat transfer analysis.

2.7.1 Structural Analysis

Structural analysis consists of linear and non-linear 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 in the material then vary with the amount of deformation as in.

2.7.2 Vibration Analysis

Vibration analysis is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibration frequency of the material which, in turn, may cause resonance and subsequent failure.

2.7.3 Fatigue Analysis

Fatigue analysis helps designers to predict the life of a material or structure by showing the effects of cyclic loading on the specimen. Such analysis can show the areas where crack propagation is most likely to occur. Failure due to fatigue may also show the damage tolerance of the material.

2.7.4 Heat Transfer Analysis

Heat Transfer analysis models the conductivity or thermal fluid dynamics of the material or structure. This may consist of a steady-state or transient transfer. Steady-state transfer refers to constant thermo properties in the material that yield linear heat diffusion.

2.8 Results of Finite Element Analysis

FEA has become a solution to the task of predicting failure due to unknown stresses by showing problem areas in a material and allowing designers to see all of the theoretical stresses within. This method of product design and testing is far superior to the manufacturing costs which would accrue if each sample was actually built and tested.

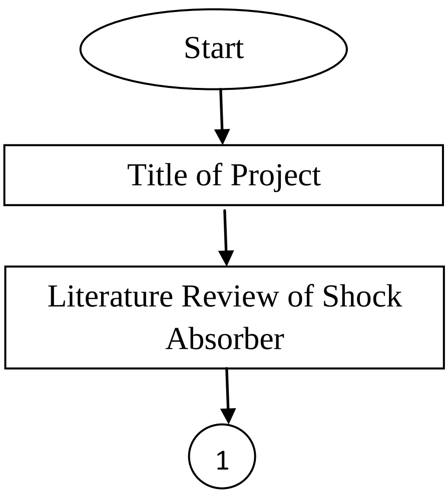
CHAPTER 3

METHODOLOGY

3.1 Introduction.

Methodology is generally a guideline for solving a problem, with specific components such as phases, tasks, methods, techniques and tools. Generally speaking, methodology does not describe specific methods despite the attention given to the nature and kinds of processes to be followed in a given procedure or in attaining an objective. When proper to a study of methodology, such processes constitute a constructive generic framework. They may be broken down in sub-processes, combined, or their sequence changed.

3.2 Diagram of Methodology.



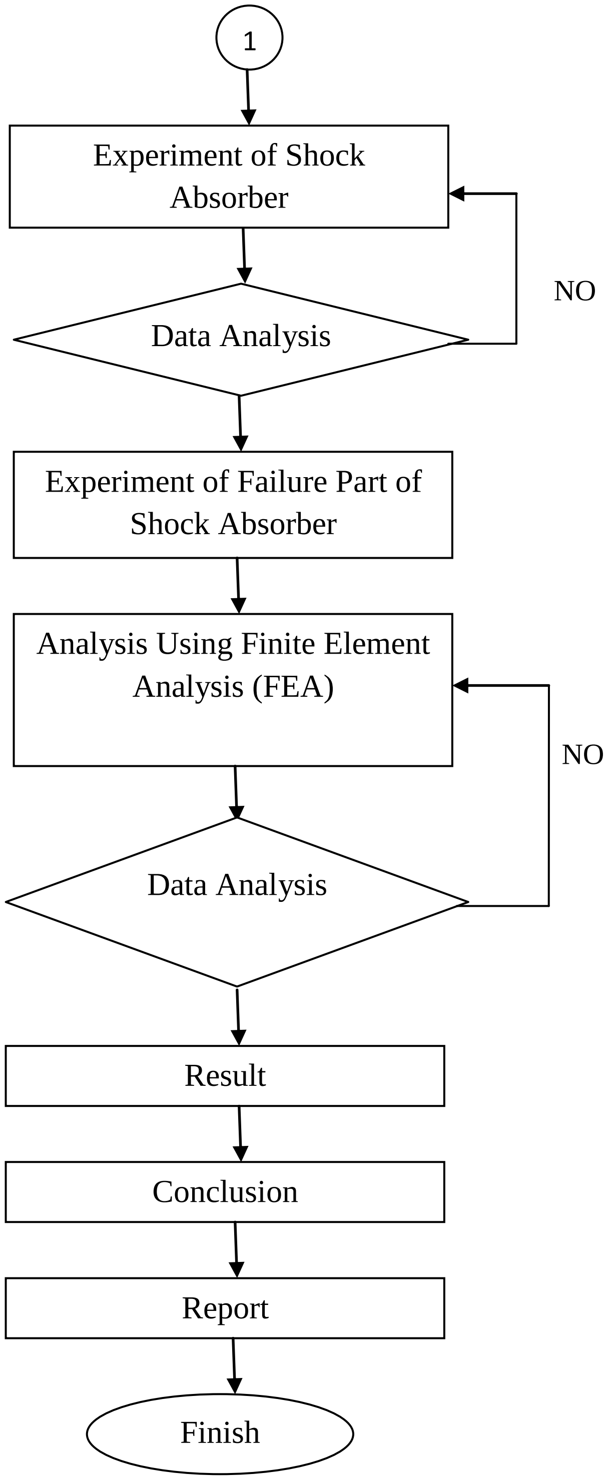


Figure 3.1: Diagram of Methodology

The project started with the selection of shock absorber as the product to be analyzed. To start with the analysis, the shock absorber components were identified. Then, the testing on the shock absorber itself was conducted to identify which components that causing the problems as stated in the problem statement.

3.3 Experiment of Shock Absorber.

Experiment of shock absorber is important step to know which part is first failure in shock absorber. There are two types of experiments which are bounce test and visual inspection of the shock absorber components.

3.3.1 Bounce Test.

A "bounce test" is a sure means of checking the dampening capability of shocks. This easy bounce test is just that, bouncing on the front of the vehicle and watching to find out how many times the vehicle bounces up and down before the bouncing stops. Too much bouncing indicates worn shocks. Basically, what need to do is bounce the car up and down using body weights a couple of times (see Figure 3.4). When discontinue bouncing and free the car, it should level off after one stroke. After releasing the vehicle, it should to bounce one time and should come back to a level spot. If the suspension continues to gyrate more than one or two times subsequent to rocking and releasing the bumper or body, shocks absorber are practically telling are old and need to be replaced. A good shock absorber will stop the vehicle from bouncing almost immediately. A bad shock absorber will not stop the vehicle from bouncing; the body will continue to bounce until all of the stored coil energy has gone.

The simplest form of suspension test is known as a “bounce” test. As can be seen in Figure 3.2, the test was conducted by lean leaving on the fender or by placing weight on the bumper before it is released suddenly. If the vehicle rebounds continually, it means that the shock absorber needs to be replaced.

Figure 3.2: Weight on bumper.

If the shock absorbers are performing well, the car will rebound once only, and then slowly return to its original position. The original position is the normal height of the vehicle as can be seen in Figure 3.3.

Figure 3.3: Normal Height

While driving, the same test can be performed by stopping the vehicle suddenly from a very low speed. If the car "bounces" up and down a couple of times when coming to rest, shock absorber needs to be replaced.

3.3.2 Visual Inspection of Shock Absorbers Components.

This experiment is conducted by using the vehicle checking form (Appendix A). The part that need be checked is damper, coil spring, oil leaking problem and bushing. The shock absorber is checked according to years and by mileages used. About 25 vehicles have been checked for this experiment.

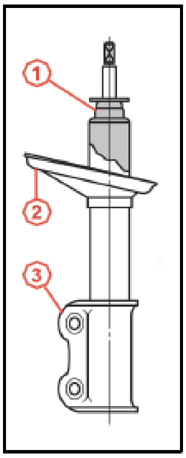
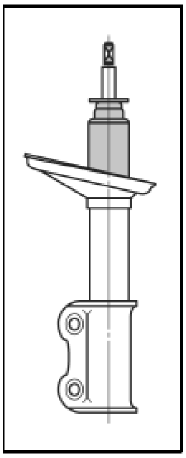
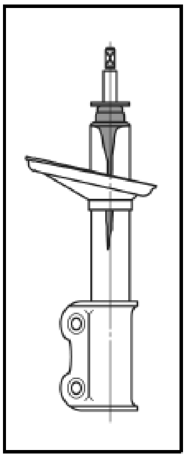
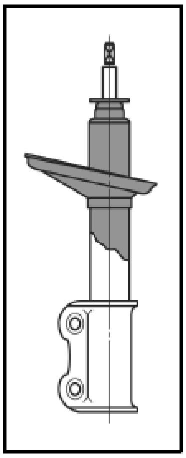
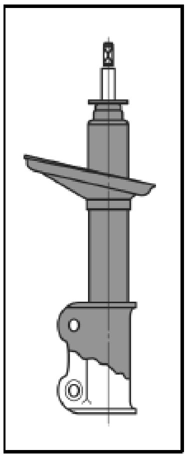
A visual inspection of the shock absorber can indicate the need for replacement. All component of shock absorber which are bushing, damper and spring were checked and evaluated to identify the main component that causing the shock absorber failure. The testing that has been done is in term of oil leaking, bushing, damper and spring performance. This test is doing to see the failure component with the visual inspection method. It also can see the real problem at the shock absorber component such as corrosion or crack.

3.3.2.1 Oil Leaking.

Shock absorbers lose a small amount of oil during use and this is considered normal. As the piston rod travels through compression and rebound strokes during shock absorber operation, a film of oil adheres to its surface, bypassing the seal. This helps lubricate and extend the life of the seal. During compression of the shock, oil is scraped off the piston rod by the seal’s dust lip and accumulates on the outer surface of the shock. Figure 3.4 show that this small amount of oil does not always indicate a defective shock absorber. Loss the oil from the shock absorber results in poor functioning and hence a loss of damping.

Figure 3.4: Oil leaking.

Table 3.1: Oil leak severity guidelines.

STRUT TYPE:	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1
Oil Leak Criteria	Figure 1.  1 Oil Seal Case 2 Spring Seat 3 Knuckle Bracket	Figure 2. 	Figure 3. 	Figure 4. 	Figure 5. 
Condition	Slight oil seepage from oil seal case	Moderate oil seepage from oil seal case	Oil leak/drip on the seal case, extending below the spring seat	Oil leak, covering top, spring seat, and part of strut body	Oil leak, covering entire strut body, spring seat, and knuckle bracket
Action	Normal oil evaporation — NOT necessary to replace the shock absorber	Normal oil evaporation — NOT necessary to replace the shock absorber	Abnormal oil leak — Replace the shock absorber	Abnormal oil leak — Replace the shock absorber	Abnormal oil leak — Replace the shock absorber

This chart in Table 3.1 shows the differences between oil visible on the shock absorber that is considered normal, and leakage that may indicate a defective shock absorber.

3.3.2.2 Bushing.

Bushings are used in many locations on the vehicle suspension system. Most bushings are made with natural rubber. However, in some cases, urethane compounds may be used. Bushings made of natural rubber offer high tensile (tear) strength and excellent stability at low temperatures. Natural rubber is an elastomeric material. Elastomeric refers to the natural elastic nature of rubber to allow movement of the bushing in a twisting plane. Movement is controlled by the design of the rubber element. Natural rubber requires no lubrication, isolates minor vibration, reduces transmitted road shock, operates noise free, and offers a large degree of bushing compliance. Bushing compliance permits movement without binding. Natural rubber resists permanent deflections, is water resistant and very durable. In addition, natural rubber offers high load carrying capabilities. A cracked or abnormally deformed mounting bushing may cause noise in the suspension when accelerating braking or going over obstacles. The bushing test is to see the condition of the bush in good condition or not. Figure 3.5 shows the condition of broken bushing.

Figure 3.5: Broken bushing.

3.3.2.3 Damper.

Shock absorbers also known as dampers are devices that offer resistance to suspension movements. They are necessary to dampen out the vertical oscillations or bounce of the suspension and car body after the springs have been deflected by road surface irregularities. Without damping, a car will bounce, pitch and roll uncontrollably which in turn affects the safety - comfort and economy (excess stress and wear on other components).

When the car wheel encounters a bump in the road and causes the spring to coil and uncoil, the energy of the spring is transferred to the shock absorber through the upper mount, down through the piston rod and into the piston. Orifices perforate the piston and allow fluid to leak through as the piston moves up and down in the pressure tube. Because the orifices are relatively tiny, only a small amount of fluid, under great pressure, passes through. This slows down the piston, which in turn slows down the spring.

There are some failures at the damper. One of the commonly failure at the damper is the rod in the cylinder is bend or scratch. Another failure is the piston in the damper is brake or scratch. This problem can affect the function of the damper because the pressure in the damper is decrease. The oil leaking is also one of the problems of damper.

Figure 3.6: Comparison between good damper and broken damper.

Figure 3.7: Crack at damper cylinder.

The other problem with the damper is the cylinder of the damper is bending because cannot support the bounce from the spring as be seen in Figure 3.8. This happens to the vehicle that have carries the over load.

Figure 3.8: Bending damper problem.

3.3.2.4 Spring.

Visual inspection of the spring is important because spring is one of the main parts at shock absorber. This inspection is to check and see the condition of the springs.

The springs support the weight of the vehicle, maintain ride height, and absorb road shock. Springs are the flexible link that allows the frame and body to ride relatively undisturbed while the tires and suspension follow the bumps in the road. When a spring is deflected, it absorbs energy. Without shocks or struts, the spring will extend and release this energy at an uncontrolled rate. The spring's inertia causes it to bounce and over-extend itself. Then it re-compresses, but will again travel too far. The spring continues to bounce at its natural frequency until all the energy originally put into the spring is used up by friction.

If the struts or shock absorbers are worn and the vehicle meets a bump in the road, the vehicle will bounce at a frequency of the suspension until the energy of the bump is used up. This may allow the tires to lose contact with the road. Stress and corrosion can cause front coil springs to fracture and fail, resulting in suspension noise and sagging.

The most common failure is spring sag. Springs that have sagged below vehicle design height will change the alignment geometry. This can create tire wear, handling problems, and wear on other suspension components. During suspension service it is very important that vehicle ride height be measured.

Figure 3.9: Spring Crack.

In Figure 3.10 shown the most commonly failure of spring. These problems happen because of the corrosion when spring used after year by year.

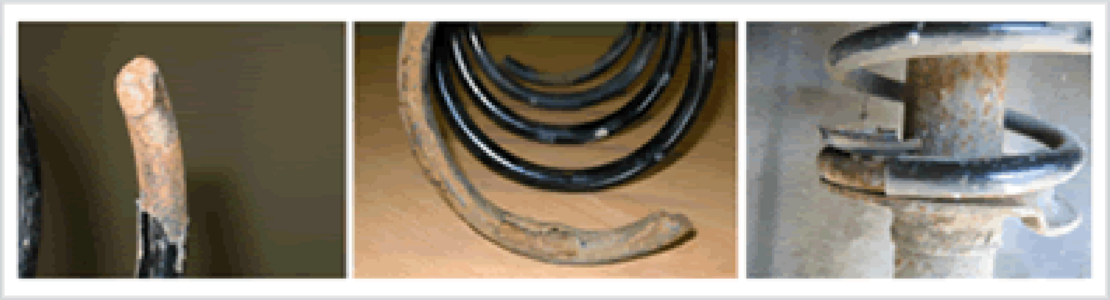


Figure 3.10: Corrosion at spring.

One other method to see the condition of the spring good or not is to see the irregular tire wear as shows in Figure 3.11. The tire wear is accentuated due to irregular contact with the road. Cupping and feathering are clear signs of defective shock absorbers. Cupping, (patchy wear also known as flat spots) can accrue on both front and rear tires as a result of poor adhesion to the road surface, when travelling over bumps and also during braking. Feathering only indicates worn shock absorbers when seen on the rear tires and is caused by loss of grip when cornering.

Figure 3.11: Irregular tires wear.

Another sign that we can see when springs have a problem is loose cornering. This is where the wheels have lost contact with the road and the vehicle rolls, excessively on corners. The vehicle is difficult to control and therefore dangerous as shows in Figure 3.12.

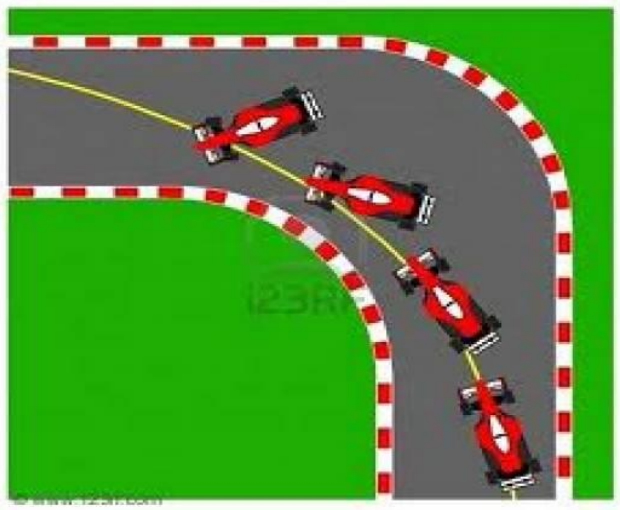


Figure 3.12: Loose cornering.

Based on the results obtained from the experiment, discussion it is found out that spring is the component that contributes to the shock absorber problems. Further experiments were conducted on the spring for the solution of the problems.

3.4 Experiment of Coil Spring.

The most commonly used spring is the coil spring. The coil spring is a length of round spring steel rod that is wound into a coil. Unlike leaf springs, conventional coil springs do not develop inter-leaf friction. Therefore, they provide a smoother ride.

Number of coil can affect the strength of the coil spring. Coil spring strength, or rate, is determined by the length and diameter of the rod. Decreasing the diameter of the rod, the number of turns, and the tightness of the turns increases the strength of the spring. Increasing the rod diameter or the number of turns, or increasing the space between turns reduces spring strength. In the bouncing test, the strength of the coil is not affected to the number of bounce. To validate that number of wire diameter and number of coil not affected to the bouncing. The experiment of wire diameter and number of active coil compared to bounce test has been conduct.

After conduct the both of experiment and see the broken of the coil spring, change the material of coil spring is another way to know the material is affected to the bounce. Most of broken coil spring is cause from corrosion at the spring. This corrosion happens because the coil spring is open to the environment conditions. When the material is change, the properties of the spring material are also change. The properties of material can affect the strength of the spring and also can reduce the corrosion happen to the spring. Because of changing material, the spring can be smooth or hardness. This can affect the bouncing at the vehicle when use in real world.

To make this experiment and analysis, steel and beryllium copper has been chosen to material of the coil spring. CATIA is use to make an analysis. The first step is to construct the model of the shock absorber. Then the material of the spring is change to compare the properties of to material and to know the material is affected to the bounce.

3.5 Analysis using Finite Element Analysis (FEA).

Finite Element Analysis (FEA) consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. Structural analysis and modal analysis are done on the shock absorber by varying material for spring, Steel Spring and Beryllium Copper Spring. The analysis is done by considering loads, vehicle weight, single person and two persons.

To make a finite element analysis, it must be have a part of the product. To draw the shock absorber, it must take all dimension of existing shock absorber. The shock absorber is draw part by part. After all part is complete draw, the assembly process has to make it to produce a one complete product. This method is using 3D design and come out with 2D drawing. The all design is in Appendix B.

Data analysis is method to define a good or best result from the Finite Element Analysis (FEA). This data analysis is very important step to achieve the objective of the project. When the result is not achieving the target, the process of FEA must be repeated until get the best result.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Data Analysis from Vehicle Checking Form.

From the vehicle checking form, the summary of the data is come out.

Table 4.1: Component problem compared to number of vehicle.

Component Problem	Number of Vehicle
Damper	4
Coil Spring	13
Oil Leaking	4
Bushing	2

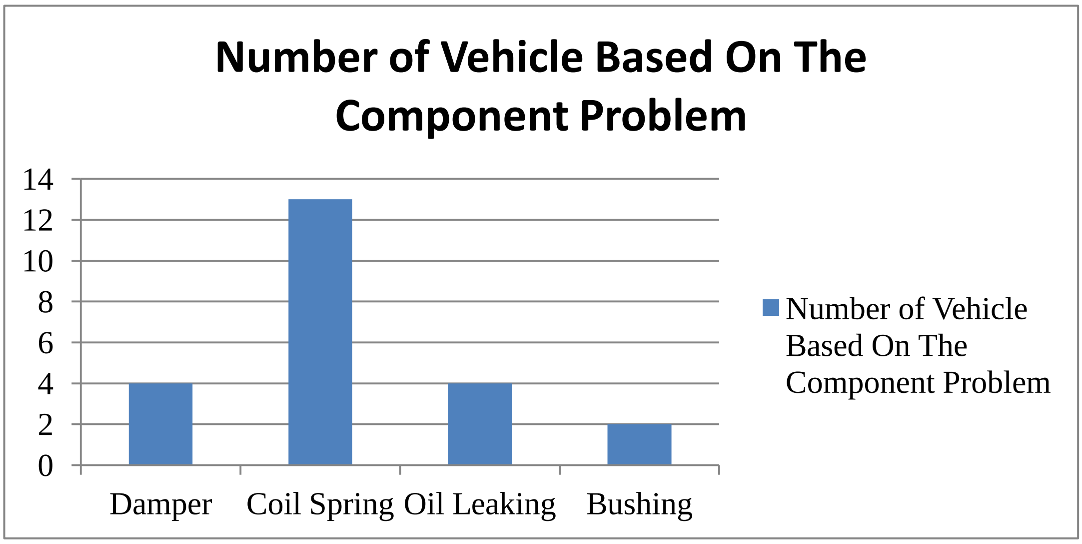


Figure 4.1: Number of vehicle based on the component problem.

From the graph in Figure 4.1, it shows the main cause of bouncing problem of shock absorber is from shock absorbers spring. There are about 13 vehicles have a coil spring problem.

4.1.1 Damper testing condition by years used.

Table 4.2: Damper testing condition by years used.

Year	**Good**	**Broken**	**Bouncing**
More Than 1 Year	✔		1
More Than 5 Year	✔		1
More Than 10 Year	✔		1
More Than 15 Year	✔		1
More Than 20 Year		✔	2

Table 4.2 is the data of damper test from the vehicle checking form. In this data, we can see that the damper is failure after used more than 20 years. For the bouncing test, after used more than 20 years, the car is bouncing more than 2 times.

4.1.2 Damper testing condition by mileage.

Table 4.3: Damper testing condition by mileage.

Mileage	**Good**	**Broken**	**Bouncing**
More Than 20,000 Kilometer	✔		1
More Than 50,000 Kilometer	✔		1
More Than 100,000 Kilometer	✔		1
More Than 150,000 Kilometer	✔		1
More Than 200,000 Kilometer		✔	2

From the Table 4.3, the damper will failure after 200,000 kilometers. In bouncing test data, the bouncing is more than 2 times when the vehicle used more than 200,000 kilometers.

4.1.3 Coil spring test condition by years used.

Table 4.4: Coil spring test condition by years used.

Year	**Good**	**Broken**	**Bouncing**
More Than 1 Year	✓		1
More Than 5 Year	✓		1
More Than 10 Year	✓		1
More Than 15 Year		✓	2
More Than 20 Year		✓	2

Coil spring is failure when use more than 10 years. For bouncing test, the vehicle use more than 15 years and above will produce more than 2 times bouncing.

4.1.4 Coil spring test condition by mileage used.

Table 4.5: Coil spring test condition by mileage used.

Mileage	**Good**	**Broken**	**Bouncing**
More Than 20,000 Kilometer	✓		1
More Than 50,000 Kilometer	✓		1
More Than 100,000 Kilometer		✓	2
More Than 150,000 Kilometer		✓	2
More Than 200,000 Kilometer		✓	2

For the mileage testing, the coil spring is failure after 100,000 kilometers used. For bouncing test, the vehicle use more than 100,000 kilometers and above will produce more than 2 times bouncing.

4.1.5 Oil leaking test by years used.

Table 4.6: Oil leaking test by years used.

Year	Good	Broken	Bouncing
More Than 1 Year	✔		1
More Than 5 Year	✔		1
More Than 10 Year	✔		1
More Than 15 Year	✔		1
More Than 20 Year		✔	2

For oil leaking test, the vehicle used more than 20 years have some oil leaking at the cylinder damper. In bouncing test, when vehicle have oil leaking at the damper, it produce more than 2 times bouncing. It happen because the damper less of oil.

4.1.6 Oil leaking test by mileage used.

Table 4.7: Oil leaking test by mileage used.

Mileage	Good	Broken	Bouncing
More Than 20,000 Kilometer	✔		1
More Than 50,000 Kilometer	✔		1
More Than 100,000 Kilometer	✔		1
More Than 150,000 Kilometer		✔	2
More Than 200,000 Kilometer		✔	2

For mileage testing for oil leaking, this problem happen when vehicle used more than 150,000 kilometers. In testing bouncing result, vehicle produce more than 2 times bouncing when used more than 150,000 kilometers.

4.1.7 Bushing test by years used.

Table 4.8: Bushing test by years used.

Year	**Good**	**Broken**	**Bouncing**
More Than 1 Year	✓		1
More Than 5 Year	✓		1
More Than 10 Year	✓		1
More Than 15 Year	✓		1
More Than 20 Year	✓		1

For bushing testing condition, the bushing is still in good condition when vehicle use more than 20 years and the bouncing of the vehicle is still good.

4.1.8 Bushing test by mileage used.

Table 4.9: Bushing test by mileage used.

Mileage	**Good**	**Broken**	**Bouncing**
More Than 20,000 Kilometer	✓		1
More Than 50,000 Kilometer	✓		1
More Than 100,000 Kilometer	✓		1
More Than 150,000 Kilometer	✓		1
More Than 200,000 Kilometer		✓	2

In mileage result for bushing, it still in good condition when use after 150,000 kilometers and the bouncing test result cause bouncing more than 2 times after 200,000 kilometer.

From all the result, the graft of bouncing versus years and bouncing versus mileages is come out. This graft show that which component that failure first after bounce test and visual inspection test.

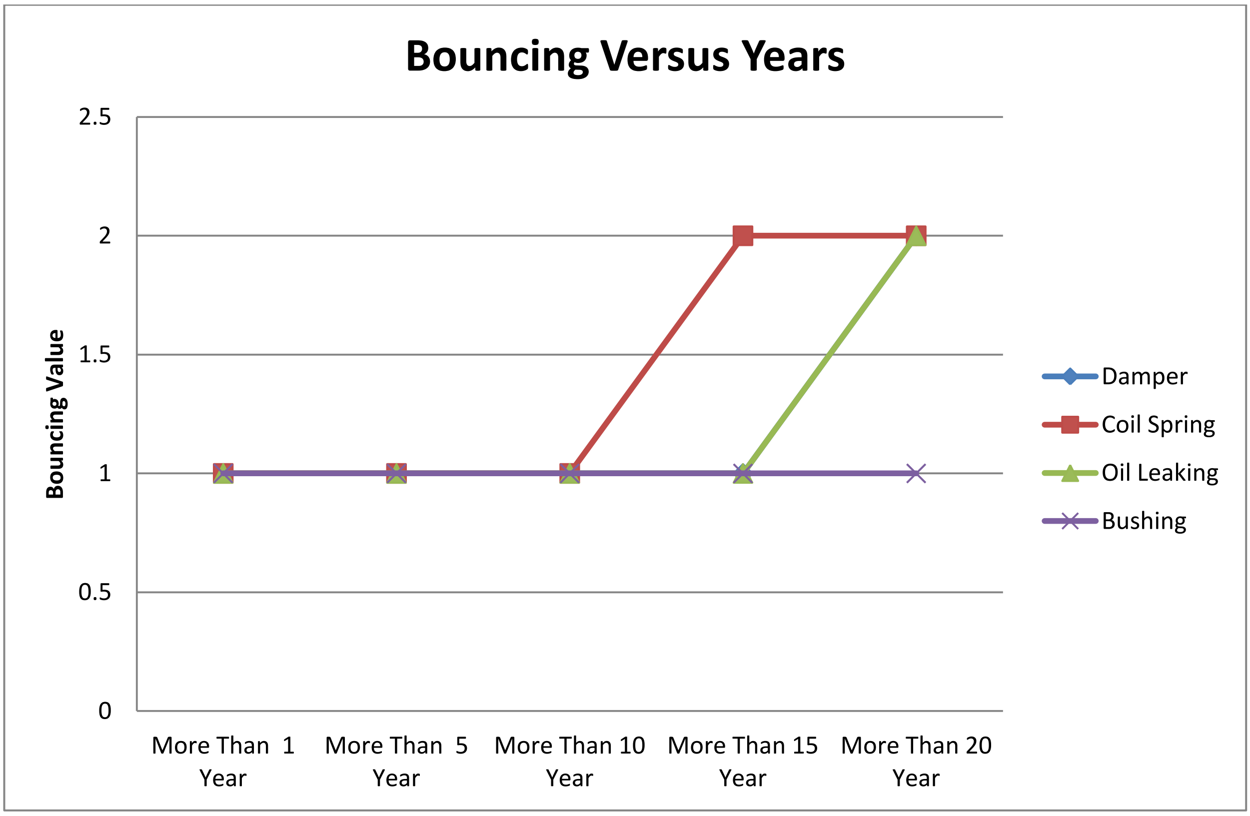


Figure 4.2: Graft Bouncing Versus Years

From the graft bouncing versus years (Figure 4.2), the coil spring is more easily to breakdown compare to the damper, oil leaking and bushing. The coil spring start failure when used more than 15 years. The graft shown that bouncing chance to two value when spring use more than 15 years.

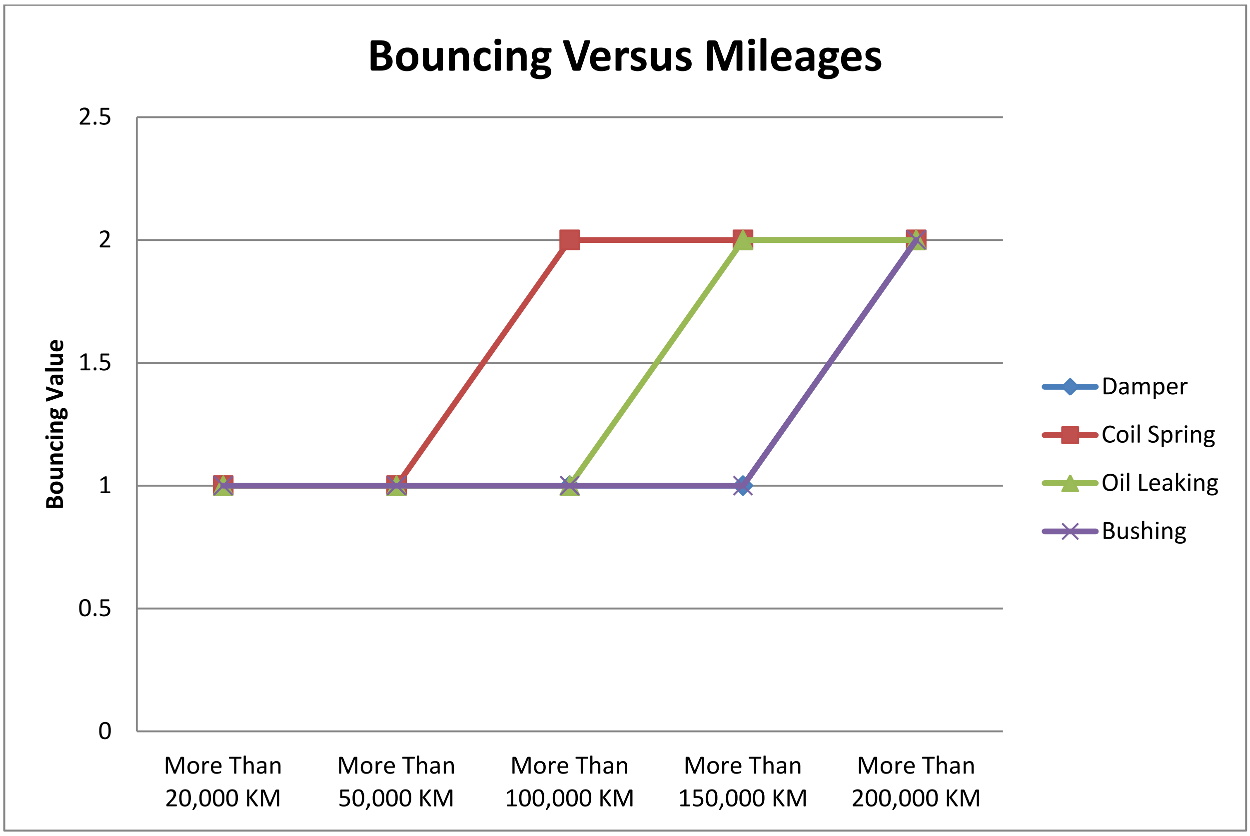


Figure 4.3: Graft Bouncing Versus Mileages

From the graft bouncing versus mileage (Figure 4.3), the coil spring is more easily to breakdown compare to the damper, oil leaking and bushing. The coil spring start failure when used more than 100,000 kilometers.

4.2 Experiment of Coil Spring.

The result from this experiment is to prove that the wire diameter and the number of active coil is not affect to the vehicle bounce.

For the experiment for the wire diameter, to validate the wire diameter is not affected to the bouncing, these test is conduct. The value of number of active coil, outside diameter of spring, free length and compressed length is constant. To calculate the spring rate, the formula of spring rate is used.

$K = Gd^4 / 8nD^3$

G= modulus of spring

(modulus of spring steel = 78 500 N/mm^2)

d= wire diameter, mm.

n= number of active coils

D= mean coil diameter (Outer diameter – Wire diameter),mm.

For example, to calculate spring rate at 9.0 mm wire diameter. This calculation is used.

$K = 78\ 500 \times 9^4 / 8 \times 6.5 \times (180 - 9)^3$

$= \underline{1980.83\ N/m}$

Table 4.10: Constants value of coil spring.

Constant Value	
Number of Active Coil	6.5
Outside Diameter of Spring	180 mm
Free Length	250 mm
Compressed Length	230 mm

Table 4.11: Wire diameter compared to bounce test.

Wire Diameter	Spring Rate (N/m)	Bounce Result
9.0 mm	1980.83	1
9.5 mm	2480.78	1
10.0 mm	3072.7	1
10.5 mm	3768.03	1
11.0 mm	4579.07	1
11.5 mm	5518.97	1
12.0 mm	6601.82	1
12.5 mm	7842.63	1
13 mm	9257.43	1
13.5 mm	10863.22	1
14 mm	12678.1	1

From the Table 4.11, the wire diameter of coil spring is not affected to the bounce of the vehicle. The small diameter of wire spring produce normal bounce and the larger diameter of the wire diameter of spring also produce the normal bounce of vehicle.

For the research of number of coil affected to the number of bouncing. The wire diameter, outside diameter of spring, free length and compressed length is constant.

For example, to calculate spring rate at number of active coil is 5. This calculation is come out.

$K = 78\,500 \times 12.5^4 / 8 \times 5 \times (180 - 12.5)^3$

$= \underline{10195.42 \text{ N/m}}$

Table 4.12: Constant value for number of coil

Constant Value	
Wire Diameter	12.5
Outside Diameter of Spring	180 mm
Free Length	250 mm
Compressed Length	230 mm

Table 4.13: Number of active coil compared to bounce test.

Number of Active Coil	**Spring Rate (N/m)**	**Bounce Result**
5	10195.42	1
5.5	9268.57	1
6	8496.19	1
6.5	7842.63	1
7	7282.45	1
7.5	6796.95	1
8	6372.14	1
8.5	5997.31	1
9	5664.12	1
9.5	5366.01	1
10	5097.71	1

From the Table 4.13 shown above, the difference number of active coil is not affected to the number of bounce. It also can prove that the new vehicle use small number of coil is same to the vehicle use more number of coil in the bounce test.

Based on the data and result shown, the number of active coil and the wire diameter of the spring are not affected to the bounce of the vehicle. To continue the research, the changing of spring material in CATIA is use to investigate that material is effect to the bounce of the vehicle.

4.3 Analysis using CATIA.

The analysis that has been conducted is using the CATIA software. This analysis is use Finite Element Analysis (FEA). This is a result of structural analysis that has been done to the shock absorber. The material has been choosing for the spring is steel and beryllium copper. For the properties of the material are describes below.

Material Properties for Steel

Youngs Modulus (EX) : 210000N/mm^2

Poissons Ratio (PRXY) : 0.29

Density :0.000007850kg/mm^3

Material Properties for Beryllium Copper

Youngs Modulus (EX) : 280000N/mm^2

Poissons Ratio (PRXY) : 0.285

Density :0.000001850kg/mm^3

The load given to the model is about 2400N. First analysis is using steel as a material of the spring (Appendix C). For the second analysis, the material of the spring is change to the beryllium copper (Appendix D). This analysis is to know the value of stress and strength of both materials using CATIA. The result that comes out from the analysis is shown in the Table 4.14.

Table 4.14: Result From FEA Analysis

STRUCTURAL ANALYSIS		**SPRING STEEL**	**BERYLLIUM COPPER**
	STRESS (N/mm^2)	0.882351	0.888703
	DISPLACEMENT (mm)	$0.141e^{-03}$	$0.106e^{-03}$
MODAL ANALYSIS	FREQUENCY (HZ)	0.803459	1.912
	DISPLACEMENT (mm)	1.721	3.545
	FREQUENCY (HZ)	0.808263	1.924
	DISPLACEMENT (mm)	1.75	3.606
	FREQUENCY (HZ)	1.257	2.996
	DISPLACEMENT (mm)	1.65	3.4
	FREQUENCY (HZ)	1.424	3.386
	DISPLACEMENT (mm)	1.818	3.745
	FREQUENCY (HZ)	1.611	3.831
	DISPLACEMENT (mm)	1.755	3.618

To validate the strength of shock absorber, structural analysis and modal analysis was done on the shock absorber by applying 2400N load on shock absorber. Analysis by varying coil spring material was done by using spring steel and beryllium copper.

By observing the analysis results, the analyzed stress values are less than their respective yield stress values. By comparing the results for both materials, the stress value is less for spring steel than beryllium copper. So for conclusion that as analysis using material of steel for coil spring is the best.

To avoid the corrosion occur at the coil spring. The one solution is to coat the coil spring with aluminum. This process must be done before painting process.

4.4 Problem Faced.

There are some problems when doing the experiment of bouncing test. The bounce test commonly testing with the body weight. At the workshop that has been going to test the shock absorber, the mechanics don't have a specific tool to check the bounce at vehicle. They only use their experience to see the bouncing of vehicle. To check the shock absorber, the mechanics only use visual inspection to see the condition of shock absorber. Because of that, the data that I get is not specific.

In the bounce test of difference parameter of the coil spring like number of coil and diameter of wire, it needs a specialist mechanic to change the spring at the same vehicle. The specialist mechanic needed because to change the coil spring is very difficult and need to assemble carefully. Another problem when test the coil spring at difference parameter is the variable coil spring is difficult to find at market place. To make this experiment, some of the coil spring is the second hand coil spring.

For the FEA analysis, there is some problem when choose a material because in the CATIA, the material is not specific. It only has a general material, so the properties of the material are not same with the properties of material at market place. Another problem is the spring that was applied with some difference material cannot be test at real world because it took a time to fabricate the spring. So the bounce test cannot be making to the spring with difference material. In FEA analysis, It can show the strength of the spring and the frequency that spring can be support.

So, for the observation the strength and stress of material of spring can affected the bouncing of the vehicle. For the problem of the corrosion at the spring, one solution that can be provided is to apply coating to the spring after it goes to the painting process. The coating is a process that can avoid the corrosion from attacking the material.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion.

The title of this project is Reduction of Shock Absorber Problem Using CATIA. One of the problems at the vehicle is bouncing problem. The first objective of this project is to study the causes of the bouncing problem at the vehicle. After make an experiment of bounce test and visual inspection test, and after make an analysis from vehicle checking form. The result that comes out had shown that the main causes of bouncing problems come from the coil spring. So it can conclude that the first objective of this project is achieved.

Second objective of the project is to compare the failure parts performance in terms of its yield strength between steel and beryllium copper. The main failure part that has found from the first experiment is spring. To make the comparison for both of material, the parameter of wire diameter and number of coil must be checked first to validate that the both of parameter of the spring is not causing to the bounce problem of the shock absorber. After make an experiment, the result show that the wire diameter and number of coil is not causing to the bounce problems.

In CATIA analysis, some of the problem is to get very specific types of material. There is only having general materials in CATIA file, for example steel and copper. To produce accurate data is very difficult because the properties of materials used are not accurate. In order to investigate that material affected the bounce, it only conclude based on the strength and stress of the analysis compared to the properties of actual spring. After make an analysis using CATIA, the best suggestion of material for spring is steel spring. For the solution of corrosion problem, the spring must be coated with some material before painting.

For the conclusion, the shock absorber manufacture should make more research to decrease a bounce problem when the shock absorber is used in longer time. Material selection for the part of shock absorber must be appropriate to the road conditions in a country to ensure that the shock absorber can survive longer.

5.2 Recommendation.

For recommendation, the bounce test should have a specific tool to make sure the result for bounce test more accurate. The test must follow a specific guideline to check the condition of the shock absorber and the guideline should be standardizing with all shock absorber manufacture. Testing must be conducted in a specific place and carried out by experts in the field of shock absorbers.

In terms of specific place, the work place that makes a test of the bouncing should have a specific machine with computer panel to show the result of the test. So, the data from the bounce test can be show at the panel and it can more specific and accurate.

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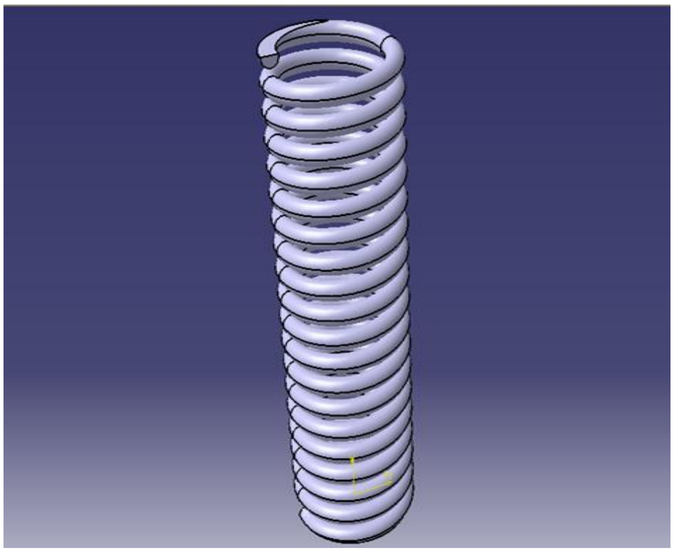
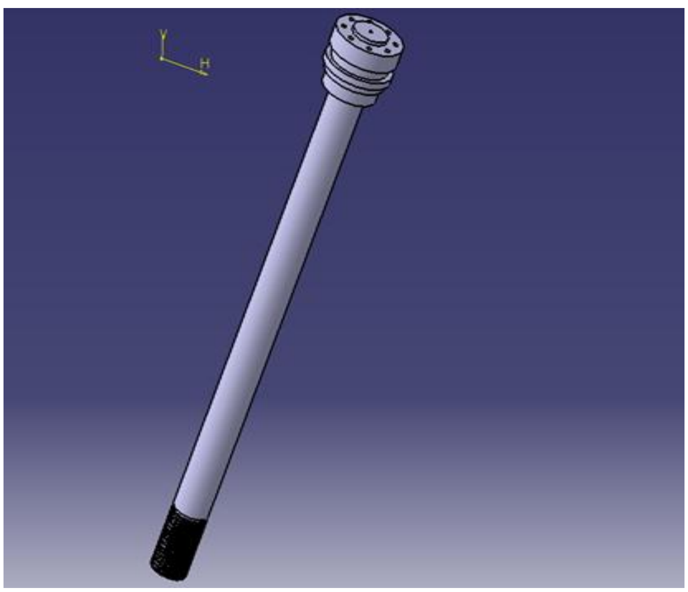
Appendix B

Spring

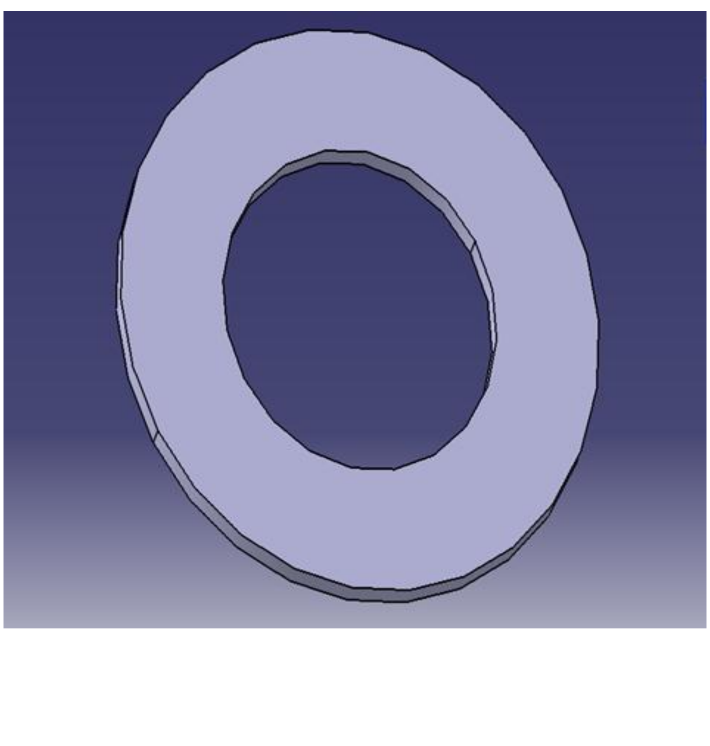


Bottom Cylinder.

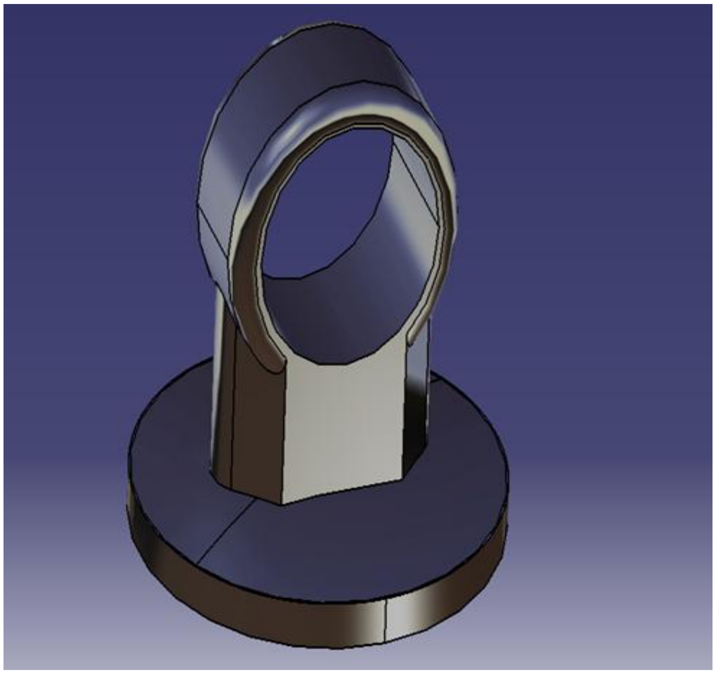


Top Cylinder.

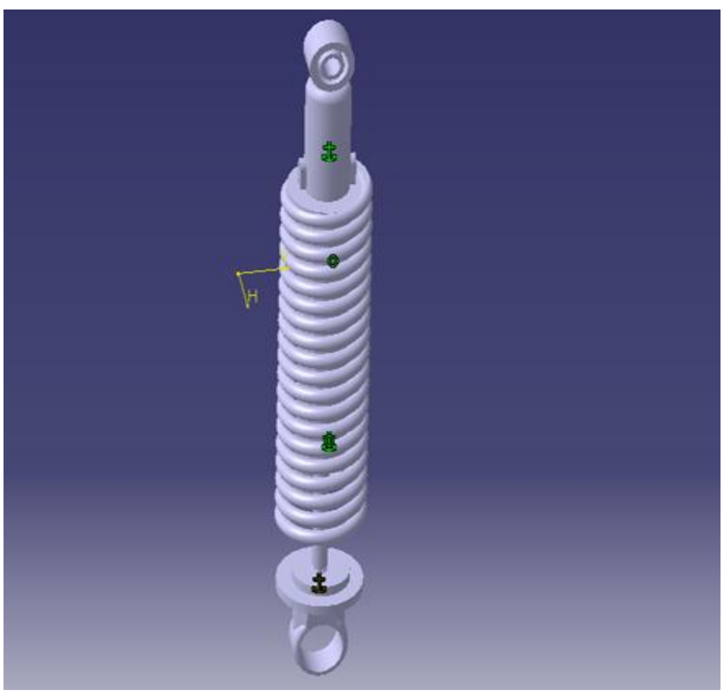
Washer.



Coupling

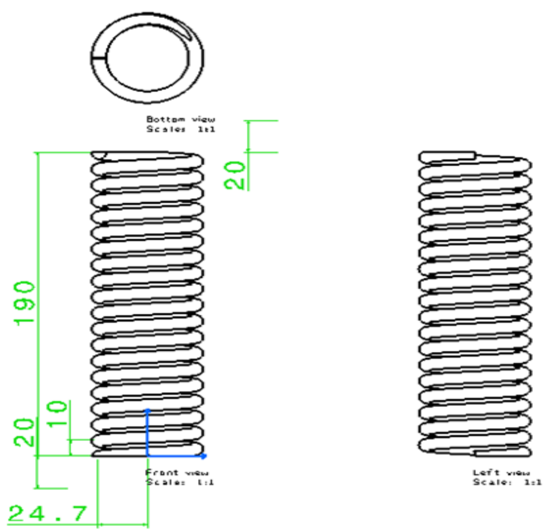


Complete Assembly 3D Model of Shock Absorber.

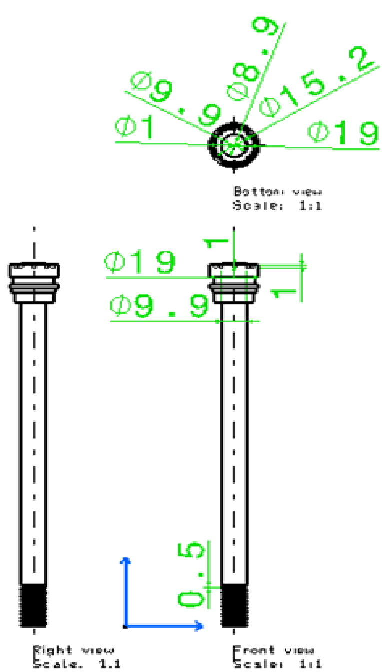


2D Drawing of Shock Absorber Parts.

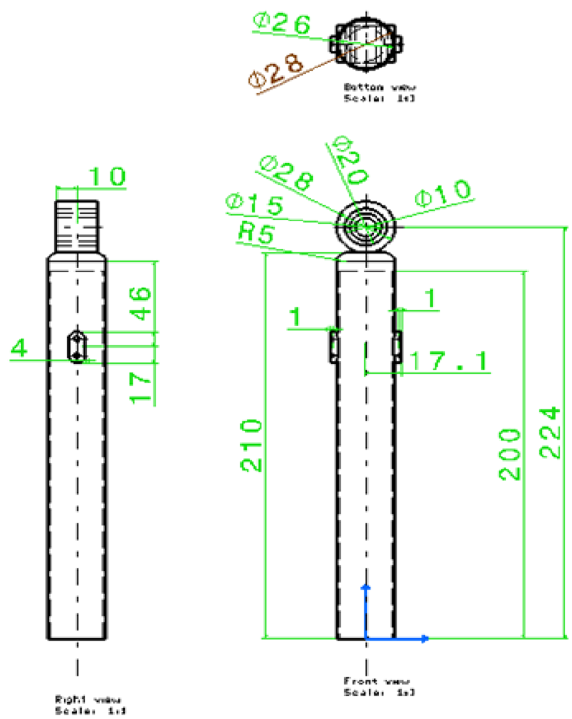
Spring



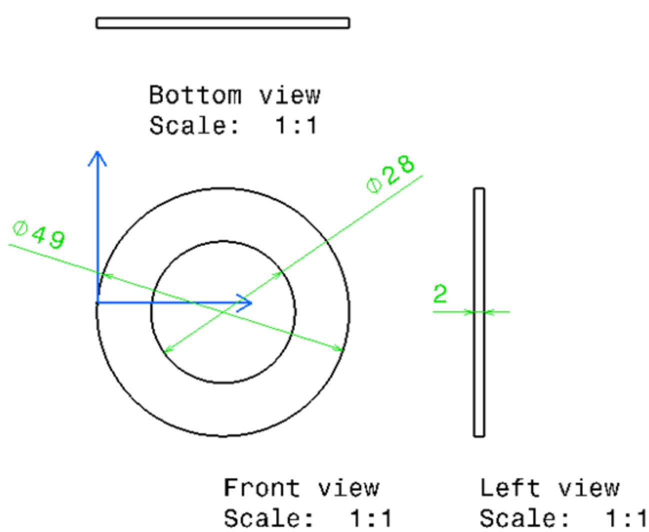
Bottom Cylinder



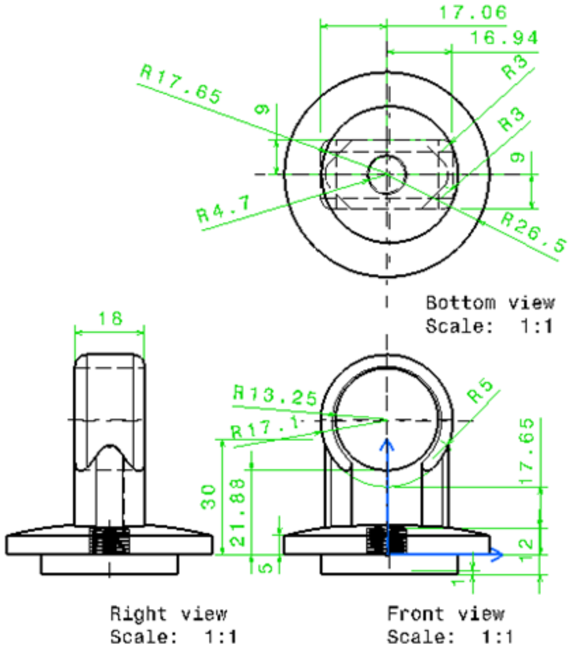
Top Cylinder.



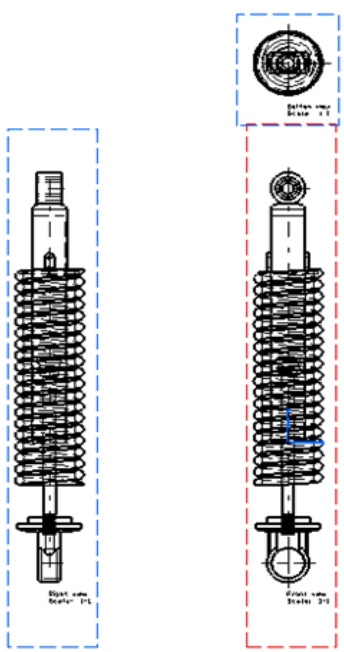
Washer.



Coupling

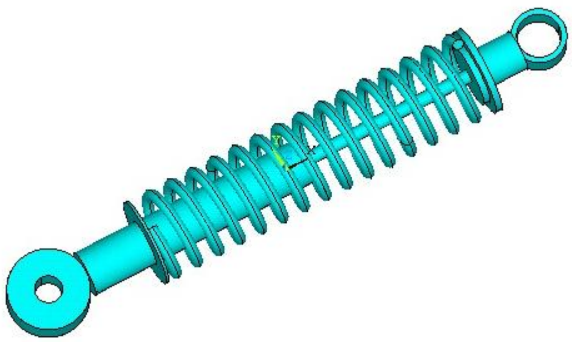


Complete Assembly 2D Drawing of Shock Absorber.



Appendix C

Analysis using Steel as spring material.



Meshed Model

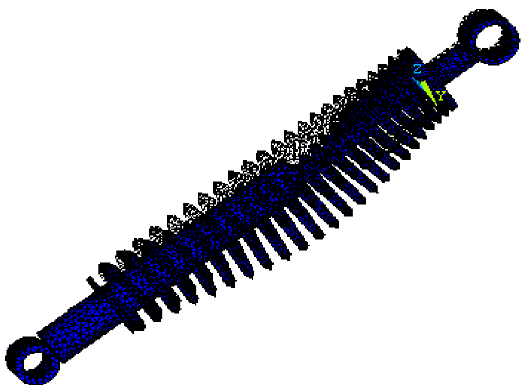
Loads

Pressure – $0.0078 N/mm^2$

Modal Analysis

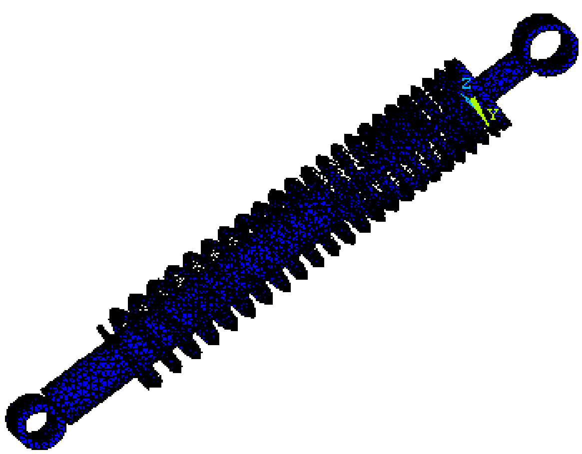
Freq : 0.803459

DMX : 1.721



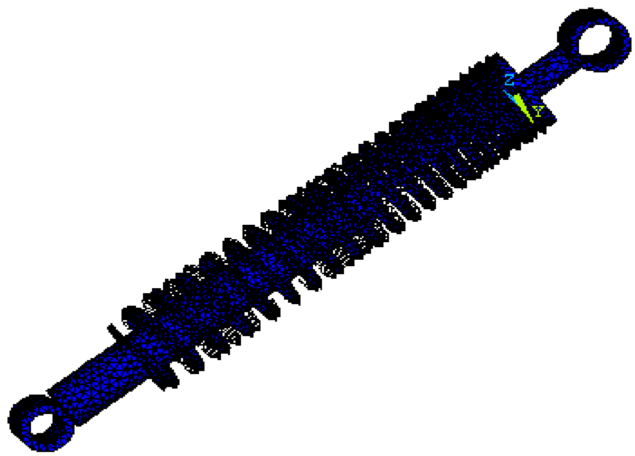
Freq : 0.808253

DMX : 1.75



Freq : 1.257

DMX : 1.65



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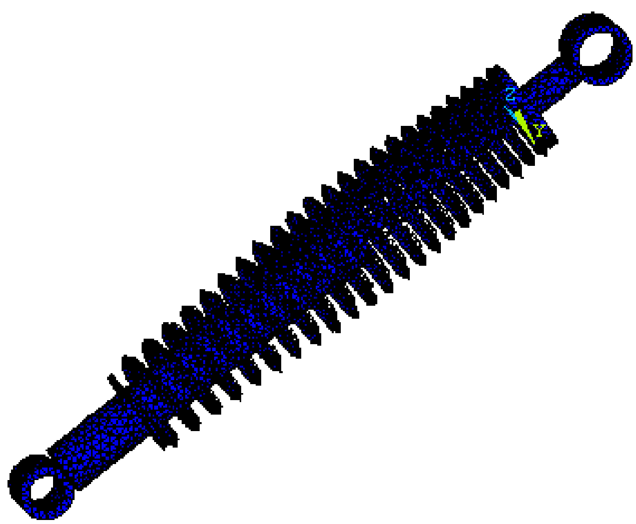
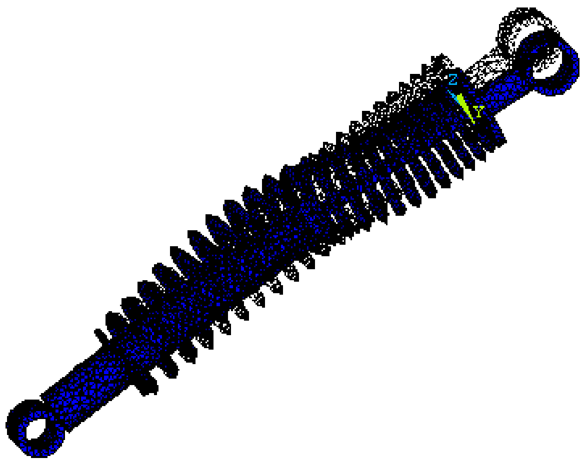
DMX : 1.818



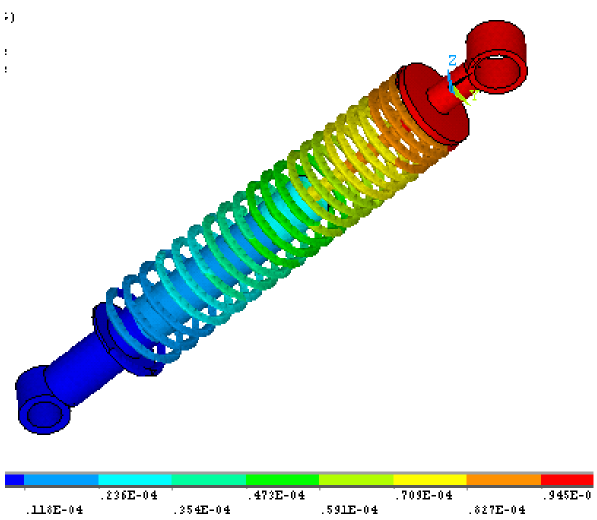
Freq : 1.611

DMX : 1.755

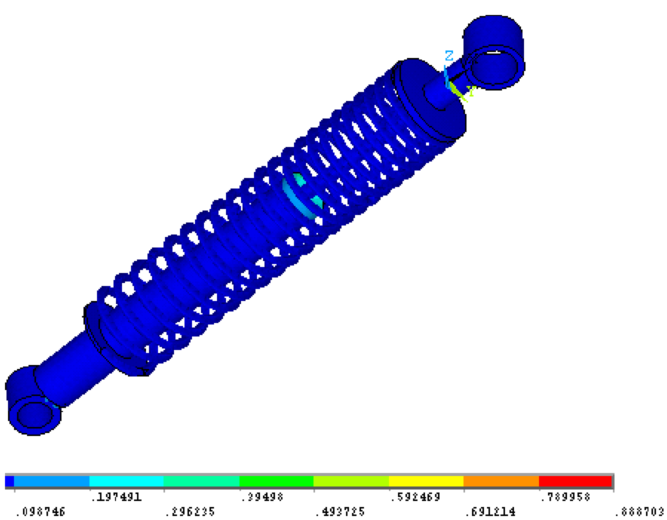


Appendix D

Analysis using Beryllium Copper as spring material.



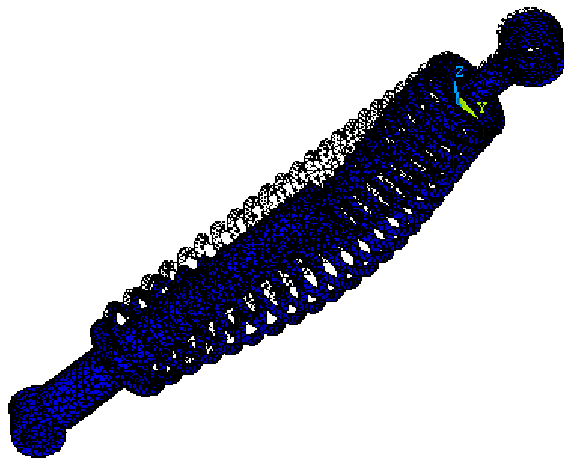
Von Mises Stress



Modal Analysis

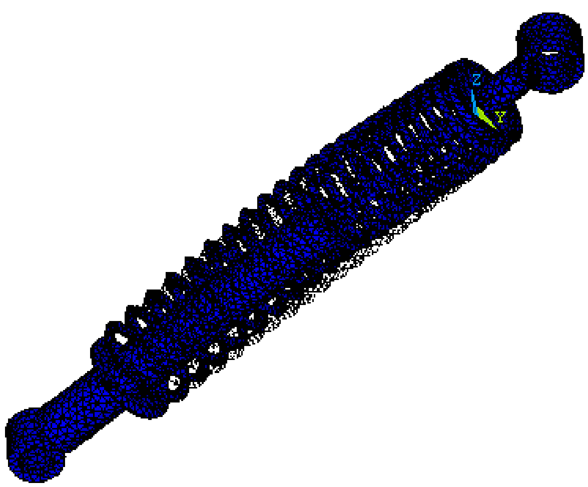
Freq : 1.912

DMX : 3.545



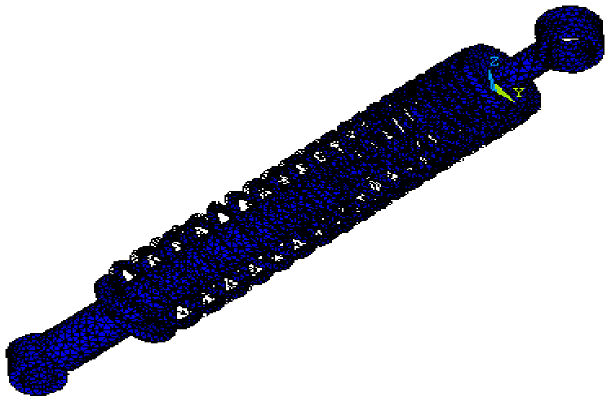
Freq : 1.924

DMX : 3.505



Freq : 2.996

DMX : 3.4



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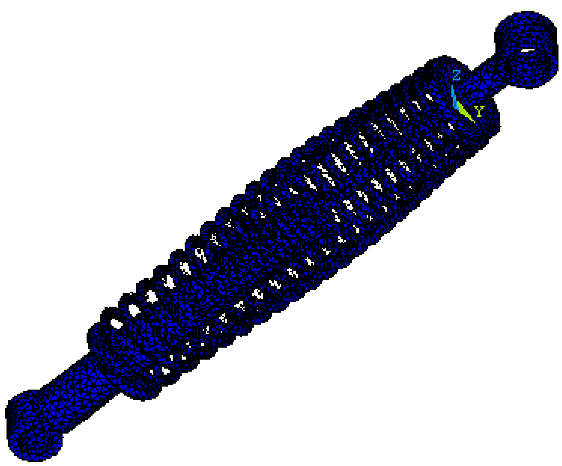
DMX : 3.745



Freq : 3.831

DMX : 3.518