ABSTRACT

The objective of this project is to investigate the vehicle ride and handling of the Myvi using the ADAMS Car simulation software and from the result obtained, studies will be carried on to develop some effective improvements to optimize comfort and handling of Myvi. The Perodua Myvi is one of the leading local cars in its class. However, it has its own share of problems when it comes to ride and handling as they had been many complains circulating around saying that the Myvi is not so comfortable both for the passengers and the drivers. Complains stated that even small flaws on the road can cause a sufficient discomfort to the drivers and passengers. The scope of study of this project will be as follow:

- Study about the vehicle ride and handling. This includes the factors that can affect the ride and handling of a vehicle, the basic vehicle ride modeling and the handling modeling.
- Study and construct the model and simulate it in the ADAMS Car software to produce the ride and handling results of the Myvi under different driving condition.
- Analyze the obtained results and propose some potential improvements that can be implemented to optimize ride and handling of the Myvi.

The methodology for this project basically has more emphasis on using the ADAMS Car software whereby the significant hardpoints are measured and inserted into the ADAMS Car modeling software to model out the original Myvi suspension system. The suspension system will then be modified in order to obtain the best feasible results. The findings that so far had been obtained are the type of suspension the Myvi is using, which is the Macpherson for the front and torsion beam at the rear. In addition, the rough calculation of the suspension ratio and the bump to scrub ratio had been calculated as well but the value might change later in the project due to some inconsistency in the measurements of the hardpoints obtained. The measurements of the hardpoints for modeling had been attempted but the result was not accurate due to some difficulty in the measuring process. Obtaining the hardpoints from Perodua itself will be the best solution. The current progress is on hold while waiting for the reply from Perodua and trying to figure out the new method of measuring the hardpoints in a more accurate way.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The Perodua Myvi was one of the most successful locally assembled cars and has always been the dominating force in its class in the local market. It's the most competitive and marketable car ever produced by Perodua when in the first six months of 2006 the sales soared to a record high of 79,738 units sold nationwide. The selling factor of the Myvi is that it's affordable and it strikes a balance between power and fuel consumption, thus winning the market of the mediocres and for those who looks for a simple car to go around the city. However, behind all these incredible statistics and selling factors, the Myvi has its own shares of complains from the customers. Many customers complained that the Myvi is pretty bumpy when it comes to tackling uneven road, which causes great discomfort to the drivers and the passengers at the back seat. The objective of this project is to investigate the vehicle ride and handling of the Myvi with the ADAMS Car software and suggest some possible improvements that can be made to the Myvi in order to maximize comfort and handling of the Myvi. The outcome of the project will answer the question of thousands of Myvi owners who are dissatisfied with the ride and handling of the Myvi

1.2 Problem Statement

The Perodua Myvi is one of the leading local cars in its class. However, it has its own share of problems when it comes to ride and handling as they had been many complains circulating around saying that the Myvi is not so comfortable both for the passengers and the drivers. Complains stated that even small flaws on the road can cause a sufficient discomfort to the drivers and passengers.

1.3 Objectives

The objective of this project is to investigate the vehicle ride and handling of the Myvi using the ADAMS Car simulation software and from the result obtained, studies will be carried on to develop some effective improvements to optimize comfort and handling of Myvi.

1.4 Scope of Study

The scope of study of this project will be as follow:

- Study about the vehicle ride and handling. This includes the factors that can affect the ride and handling of a vehicle, the basic vehicle ride modeling and the handling modeling.
- Study and construct the model and simulate it in the ADAMS Car software to produce the ride and handling results of the Myvi under different driving condition.
- Analyze the obtained results and propose some potential improvements that can be implemented to optimize ride and handling of the Myvi.

CHAPTER 2
LITERATURE REVIEW

2.1 Real-Time Simulation of Vehicle Dynamics: On-line Control and Handling Investigations

In this paper, Vogel described about the real time vehicle dynamics simulation program called VEDYNA. For dynamical simulation, cars are modeled as multi body system (MBS) [5]. VEDYNA utilizes the MBS of the test vehicle and a specially adapted, efficient integration algorithm and the optional multi-processor hardware. The model will basically be divided into three main parts [9]:

a) Car's Structure – A system of a nine rigid bodies.
b) Submodel for drive train.
c) Submodel for steering system and tyres.

The mathematical modeling of the MBS will give a total of 24 first order ordinary differential equations (ODE) for the vehicle body and the axles and 8 differential equations for the tires. A model of the power train is given by 19 differential equations including four equations for the angular velocities of the wheels while five differential equations are used to model the dynamics of the steering system. [6]

The VEDYNA will simulate a virtual "driver", which is able to guide the virtual car along a nominal track on a virtual road at high speed and in extreme driving condition where skidding and sliding effects occurs. The mathematical modeling together with the virtual driver program will thus simulate the car in various maneuvering conditions and the handling of the car can be evaluated from the results obtained. The VEDYNA has the advantage over the ADAMS or SIMPACK as the VEDYNA consume less time in real time simulation as compared with its counterparts. [6]

2.2 Ride and Handling Investigation

The ride investigation in this case was conducted with the MSC ADAMS simulation software. The paper reports on the investigation to determine the spring and damper settings that can optimize ride comfort of an off-road vehicle. The investigation was performed with the Dynamic-Q algorithm on a Land Rover Defender 110 modeled in MSC.ADAMS simulation software for speeds ranging from 10 to 50 km/h. A full vehicle model of a Land Rover Defender 110 was modeled in the multi body system (MBS) dynamics software package MSC.ADAMS, version 12. The model consists of 16 unconstrained DOF, 23 moving parts, 11 spherical joints, 10 revolute joints and 9 Hookes joints. A variable torque dependent on the difference between the instantaneous and the desired speed drives the wheels. For the tyres the MSC.ADAMS 521 interpolation tyre model is used [7]. In this report, the end result shows that the optimization of the suspension settings using one road and speed will improve ride comfort on the same road at different speeds. Generally, to improve ride comfort, damping has to be lowered than the standard (compromised) setting, the rear spring as soft as possible and the front spring ranging from as soft as possible to stiffer depending on road and speed conditions. Ride comfort is most sensitive to a change in rear spring stiffness. [8]

Another alternative to investigate the ride and handling is by using the gradient-based approximation method to optimize the suspension design by using computational method with severe inherent noise. The Sequential Quadratic Programming algorithm and the relatively new Dynamic-Q method are the two successive approximation methods used to conduct this test. The use of forward finite differences and central finite differences for the determination of the gradients of the objective function within Dynamic-Q is also investigated [11]. In this case, an off-road vehicle is modeled in ADAMS, and coupled to MATLAB for the execution of the optimization process. The full vehicle ADAMS model includes suspension kinematics, a loaddependent tyre model, as well as non-linear springs and dampers [11]. Up to four design variables are considered in modeling the suspension characteristics. It is found that both algorithms perform well in optimizing handling. However, difficulties are encountered in obtaining improvements in the design process when ride comfort is considered. Nevertheless, meaningful design configurations are still achievable through the proposed optimization process, at a relatively low cost in terms of the number of simulations that have to be performed.

In some cases, the vehicle handling and stability will affect the vehicle drift while the vehicle is braking in straight line. Jaguar and Ford had funded a joint research to investigate this matter. The factors that can cause brake drift are [12]:

a) Suspension Geometry.
b) Suspension Alignment.
c) Braking System.

The vehicle modelling and analysis is performed in a virtual environment where attempts have been made to match the CAE model as closely as possible to an on road vehicle. Suspension parameters refer to suspension geometry and alignment settings, which depict the characteristics (lateral acceleration, yaw velocity, toe/ caster angles) of a vehicle in a transient maneuver. These parameters are primary to a vehicle directional stability as they define the vehicle front suspension geometry [12]

2.3 Tyre Model

Tyre plays an important role in the investigation of the ride and handling a vehicle. Generally, Magic Formula tyre modeling (MF-Tyre is a part of ADAMS/Tire) allows an accurate and efficient description of tyre-road interaction forces required for any usual vehicle handling simulation. When it comes to modeling of tyre behavior at higher frequencies and short road obstacles, which are important for vehicle ride assessment, advanced chassis control systems and chassis system vibrations, a more sophisticated approach is required. In order to meet up to these expectations, TNO had developed the SWIFT (**S**hort **W**avelength **I**ntermediate **F**requency **T**yre) model, which is based upon a rigid ring type of tyre model. The SWIFT model is able to describe dynamic tyre behavior for in-plane (longitudinal and vertical) and out-of-plane (lateral, camber and steering) motions up to about 60 Hz, and for road obstacles with short wavelength. For reasons of accuracy and calculation speed the SWIFT model has been programmed as a semi-empirical model which is derived using advanced physical models and dedicated high frequency tyre measurements to assess speed effects in tyre behavior [13].

During the development of SWIFT much attention has been paid to validation of the model with advanced high frequency tyre testing. Similar to the MF-Tyre module, the SWIFT-Tyre has been linked to ADAMS using a Standard Tyre Interface and has been extensively validated with tyre measurements especially performed with high frequency excitations. In addition robustness, user friendly-ness and backward compatibility with MF-Tyre have been given high priority. Following are the advantageous of the SWIFT [13]:

- Rigid Ring modelling for tyre belt vibrations up to 60 Hz
- Semi-emperical for optimal accuracy and calculation speed
- Elaborate contact model for short wavelength slip variations (wavelengths > 0.2 m)
- Effective inputs for discrete obstacles
- Magic Formula for slip force calculation
- Validation with realistic tyre test data

2.4 National Highway Safety Administration: roll over metrics and rating

Roll over is very much related to handling, although handling capability and roll over tendency are not similar, roll over considerations as depicted from the National Highway Safety Administration (NHTSA) survey was investigated. Under handling, the response properties of a vehicle perceived and experienced by the driver acting as the controller would be considered. Roll over on the other hand pertains to the tendency of the roll amplitude and motion of the vehicle to increase progressively due to steering induced disturbance. In an effort to regulate roll over propensity, NHTSA required a safety standard ‘‘that would specify minimum performance requirements for the resistance of vehicles to roll over in simulations of extreme driving conditions’’. The conclusion was that ‘‘vehicle roll over response is dominated by the vehicles rigid body geometry with dynamic contributions from suspension effects’’. NHTSA_s analysis [14] of 100 000 single-vehicle roll over crashes eventually focused on two static measurements: tilt table angle (the angle at which a vehicle will begin to tip off a gradually tilted platform) and critical sliding velocity (the minimum velocity needed to trip a vehicle which is sliding sideways)

– both measurements address situations in which a vehicle encounters something that trips it into roll over (a curb, soft dirt, the tire rim digging into the pavement). Taking into account safety objectives, the following vehicle stability metrics were considered
as having a potentially significant role in roll over: centre of gravity height, static stability factor (SSF), tilt table ratio, side pull ratio, wheelbase, critical sliding velocity, roll over prevention metric, braking stability metric and percentage of total weight on the rear axle. Vehicle stability metric in this case indicates a measured vehicle parameter thought to be related to the vehicle's likelihood of roll over involvement [14].

2.5 Handling performance of a truck-trailer vehicle

In his survey of the handling performance of truck-trailer vehicles, Vlk [15] mentions the following criteria that were used: lateral stability and movement, Hurwitz criterion for stability, yaw angle, lateral displacements in tyre road contact paths, lateral play at the hitch, side amplitude of trailer, frequency of trailer yaw oscillations, yaw rate gain, lateral axle deviation, side slip angle, overturning risk, lateral acceleration, change of wheel vertical loads, longitudinal tyre slip and cornering forces as a result of directional response due to braking. He also mentions the experiments by Zhukov who ascertained that the roll rotation of a trailer was accompanied by a lateral displacement of both truck and trailer from their direct path. The most outstanding correlation found was between trailer roll and yaw.

2.6 Stability during Severe Maneuver.

EL-Gindy and Ilosvai [16] mentions a study of Yim et al. that indicated that the slip-ratio of the front wheels relative to that of the rear wheels correlated with stability. El Gindy investigated lane change and braking maneuvers on dry and wet P.E. Uys et al. / Journal of Terramechanics 43 (2006) 43–67 51 asphalt and uses lateral acceleration, yaw rate, lateral displacement and heading angle to determine stability [16]. It is apparent from this survey that measurement of vehicle handling is not a clear-cut matter. The aim of the survey was to determine whether a metric has been described that could be used to decide when a switch over from a soft to a hard suspension setting and vice versa should occur. It should also be such that it can be used to optimize the suspension settings. It is concluded from the information presented here that no such unambiguous metric is apparent. There are, however, some parameters that are worth considering and these were used to direct the experimental investigation.

CHAPTER 3: METHODOLOGY

3.1 Methodology

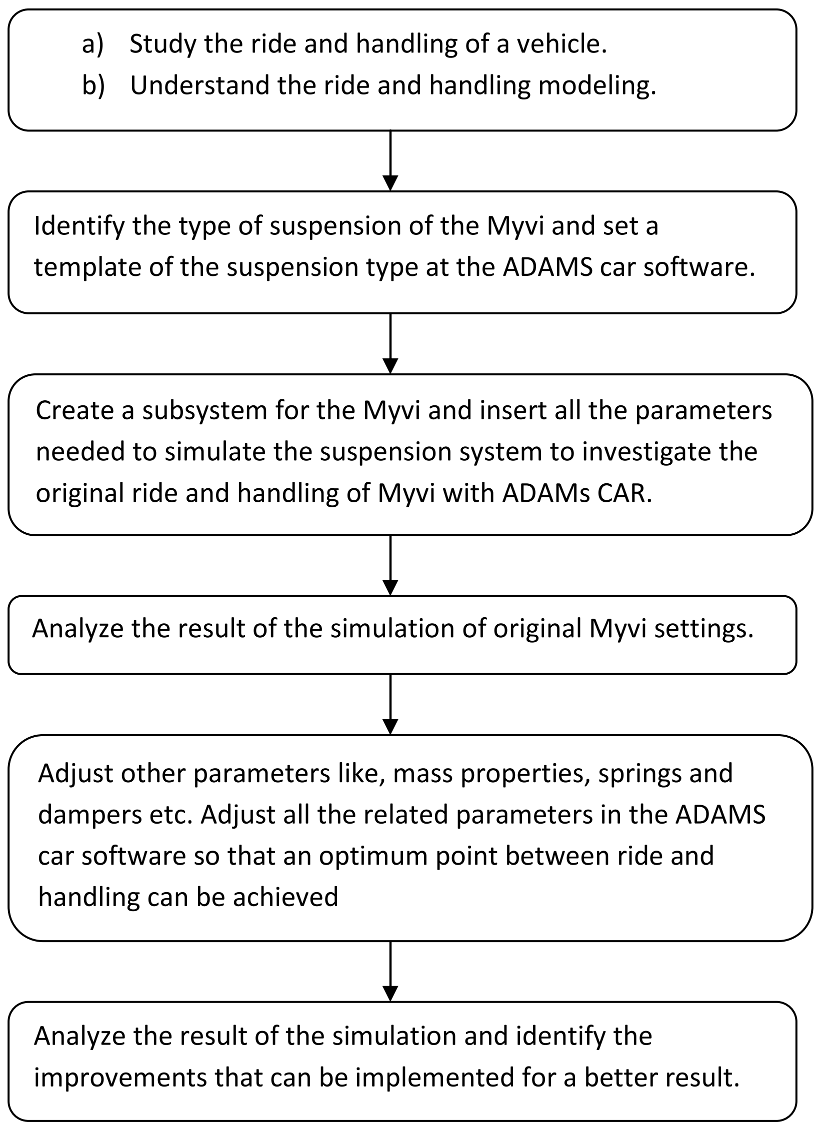


Figure 1: Initial Methodology

3.2 Project Activity

Studies had been done and the Vehicle Chassis Design classes had been attended to further strengthen the knowledge needed to complete this project. The type of suspension used in Myvi had also been identified and the current progress is at the stage of obtaining the hardpoints for Myvi. The rough calculation of the suspension ratio and the bump to scrub ratio had been calculated as well but the value might change later in the project due to some inconsistency in the measurements of the hardpoints obtained. The measurements of the hardpoints had been attempted but the result was not accurate due to some difficulty in the measuring process. Obtaining the hardpoints from Perodua itself will be the best solution. The current progress is on hold while waiting for the reply from Perodua and trying to figure out the new method of measuring the hardpoints in a more accurate way.

3.3 Key Milestone

Suggested Milestone for Final Year Project I

No	Detail/Week	1	2	3	4	5	6	7	8	9		10	11	12	13	14
1	Selection of Project Topic	■	■								Mid-semester break					
2	Preliminary Research Work		■	■	■											
3	Submission of Preliminary Report				●											
4	Project Work					■	■	■	■	■						
5	Submission of Progress Report								●							
6	Seminar (compulsory)								●							
7	Project work continues											■	■	■	■	■
8	Submission of Interim Report Final Draft															●
9	Oral Presentation											During study week				

● Suggested milestone

■ Process

Figure 2(a): Key Milestone For FYP I

Months/Details	January	Feb	March	April	May
Obtaining accurate parameters					
Running initial simulations					
Submission of Progress Report.					
Analysis of Simulations					
Improvements of Simulations					
Submission of Final Report					
Modeling of the suspension in ADAMS Car.					

Figure 2(b): Key Milestone For FYP II

3.4 Gantt Chart

Months/Details	January	February	March	April	May
Obtaining accurate parameters					
Run initial simulation					
Submission of Progress Report.					
Analysis of Simulations					
Improvements of Simulations					
Submission of Final Report					
Modeling of the suspension in ADAMS Car.					

Figure 2(c): Gantt chart FYP 2

3.5 Tools and Equipments.

The tools and equipments used are as follow:

a) 3 meter measuring tape.

b) Strings.

c) ADAMS Car software.

d) CATIA Software

e)

CHAPTER 4: RESULTS & DISCUSSION

4.1 Data Gathering & Analysis

Based on the research and findings from various sources, it has been identified that the basic Myvi suspension system are as followed:

a) Front Suspension – Universal Macpherson strut with lower L-arms and coil spring.

b) Rear Suspension – Torsion beam with coil spring.

By indentifying the type of suspension used in a Myvi, we then can try to simulate the suspension system of the Myvi in ADAMS CAR.

4.1.1 Macpherson Strut Suspension System (Front)

Generally, the Macpherson strut is a type of car suspension system which uses the axis of a telescopic damper as the upper steering pivot. The Macpherson Strut has the lay out of a wishbone or a substantial compression link stabilized by a secondary link which provides a bottom mounting point for the hub or axle of the wheel. This lower arm system provides both lateral and longitudinal location of the wheel. The upper part of the hub is rigidly fixed to the inner part of the strut proper, the outer part of which extends upwards directly to a mounting in the body shell of the vehicle (Refer to Figure3). In the automotive market nowadays, the

Macpherson Strut system is hands down, the most widely used front suspension system due to its simplicity and relatively low manufacturing cost, which makes it even more competitive.

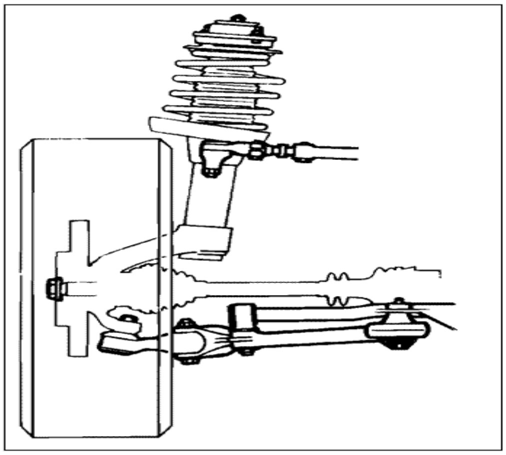


Figure3: Macpherson Strut

Although it's the most popular front suspension system used in the market, it's inevitable that the Macpherson has its own share of disadvantages in terms of ride comfort and handling of the vehicle. To begin with, it's a very tall assembly, making this system impractical on race cars, which means that you won't be able to lower a car with MacPherson Struts as much as other systems. Macpherson Struts also have a problem with the amount of room available for wider wheels, without increasing the scrub radius [18]. The scrub radius is the distance from the ball joint line to the centerline of that wheel. Basically you want to minimize the scrub radius because any bump or cornering force that is applied to the tire can exert a twisting force on the steering that is proportional to the length of the scrub radius. So if you were able to get the scrub radius to be zero, the car wouldn't really need power steering. This means that getting wider wheels will increase the scrub radius, and you will need to use more effort to steer the car. Another disadvantage of MacPherson Strut suspensions is that there is very little camber change with vertical suspension movement which in turn may affect the ride comfort. This means that the tires on the outside of the turn are going to have positive camber as the body rolls. This means that the contact patch of the outside tires is reduced as the body rolls during a turn. Since the outside tires are the ones that are providing the most cornering force, you want them to have as large a contact patch as possible. Due to its little camber change in vertical movement and sideways movement, it confined the engineer's freedom to choose camber change and roll center.

The wheel tends to lean with the body, leading to understeering when the vehicle is attacking a corner. Another drawback is that it tends to transmit noise and vibration from the road directly into the body shell, giving higher noise levels and a harsh feeling to the ride [19]. With the dynamics of Myvi and its suspension systems, when one needs to attack a bend or a corner, it has to be taken care of very well to avoid understeering and drifting.

4.1.2 Torsion Beam Rear Suspension.

Torsion Beam suspension system is a vehicle suspension system that uses a torsion bar as its main weight bearing spring. One end of a long metal bar is attached firmly to the vehicle chassis; the opposite end terminates in a lever, mounted perpendicular to the bar that is attached to a suspension arm, spindle or the axle (Refer to Figure4). Vertical motion of the wheel causes the bar to twist around its axis and is resisted by the bar's torsion resistance. The effective spring rate of the bar is determined by its length, diameter and material. The torsion beam suspension is mostly being used at the rear of the vehicle. The settings of the torsion bar can be changed depending on the specification of the vehicle. Manufacturers change the torsion bar or key to adjust the ride height, usually to compensate for heavier or lighter engine packages. While the ride height may be adjusted by turning the adjuster bolts on the stock torsion key, rotating the stock keys too far can bend the adjusting bolt and place the shock piston outside the standard travel [16]. Over-rotating the torsion bars can also cause the suspension to hit the bump stop prematurely, causing a harsh ride.

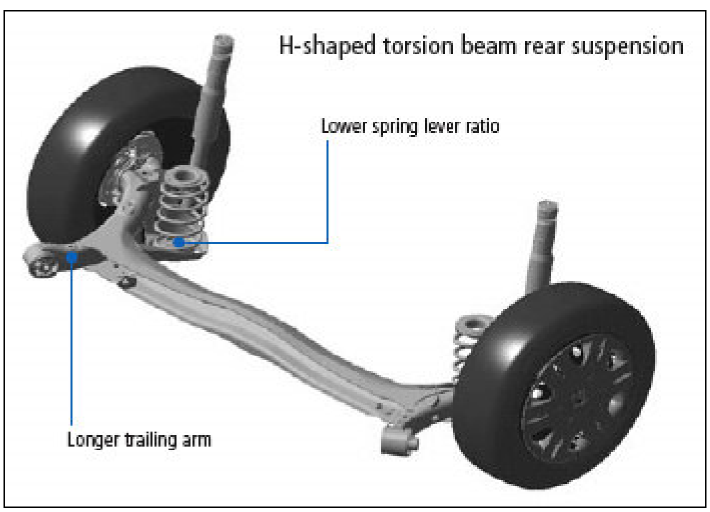


Figure 4: Torsion Beam.

Torsion beam suspension has its own share of advantages and disadvantages. The advantages are durability, easy adjustability of ride height, and small profile along the width of the vehicle. It takes up less of the vehicle's interior volume compared to coil springs. The disadvantages counterpart is that the torsion bars, unlike coil springs, usually cannot provide a progressive spring rate, forcing designers to compromise between ride quality and handling ability—progressive torsion bars are available, but at the expense of durability since they have a tendency to crack where the diameter of the bar changes. In most torsion bar systems, especially Chrysler's, ride height (and therefore many handling features) may be adjusted by bolts which connect the torsion bars to the steering knuckles and require nothing more than crawling under the car with a wrench in hand. In most cars which use this type of suspension, swapping torsion bars for those with a different spring rate is usually very handy.

In comparison with other types of suspension systems such as double wishbones, multi-link and trailing arm suspensions; it engages little width of the car, thus enable greater rear seat room. It is cheaper too. Compare with MacPherson strut, its shock absorber is shorter and can be inclined steeply away from the vertical, thus engage less boot space. In fact, torsion beam suspension is only half-independent - there is a torsion beam connecting both wheels together, which allows limited degree of freedom when forced [17]. For some less demanding compact cars, this saves the anti-roll bars. On the other hand, it doesn't provide the same level of ride and handling as double wishbones or multi-link suspensions; although in reality it is superior to its only direct competitor, MacPherson strut. Most of the Europe's best handling GTIs employed this suspension.

4.2 Suspension Ratio and Scrub to Bump Ratio

The measurements needed to calculate the suspension ratio and the scrub to bump ratio had been obtained from the lab. These measurements are used to construct a kinematic analysis of the front suspension in order to obtain the scrub to bump ratio and suspension ratio of Myvi. Figure 5 shows the 2D drawing of the Macpherson suspension and Figure 6 shows the kinematic diagram of the suspension that will be used to compute the scrub to bump ratio and suspension ratio.

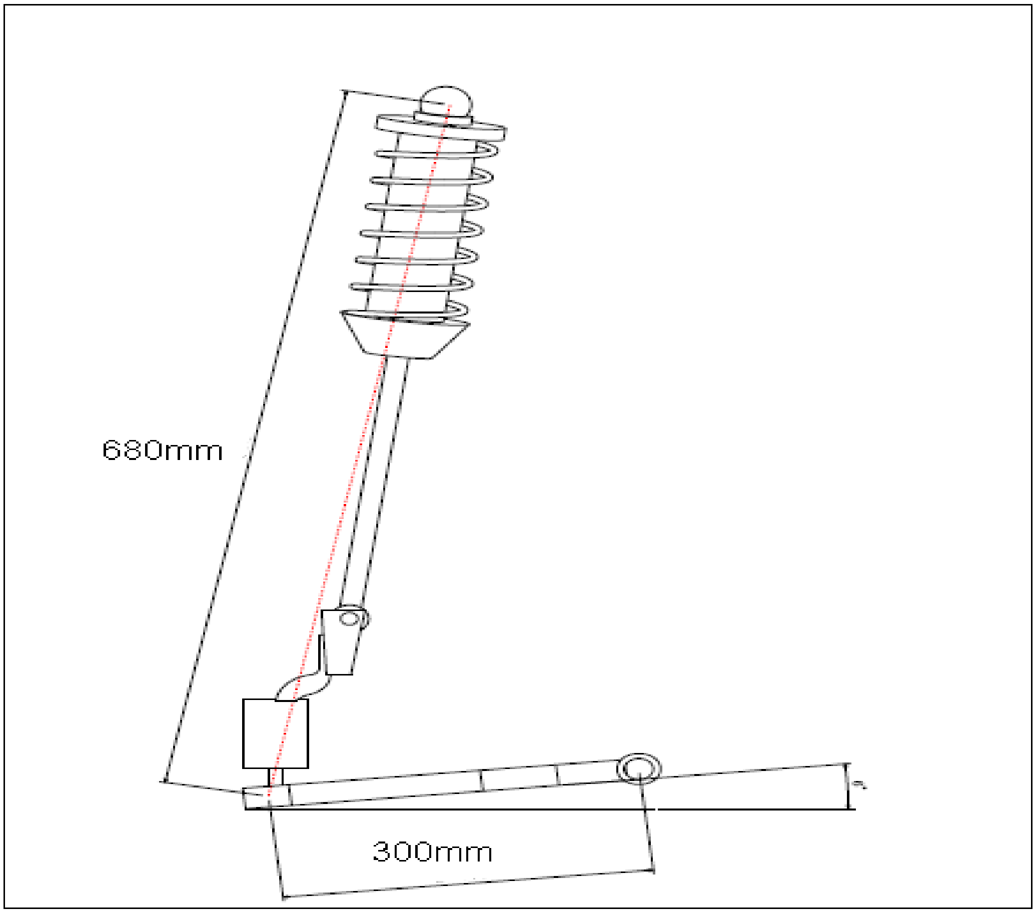


Figure 5: 2D drawing of the Macpherson suspension

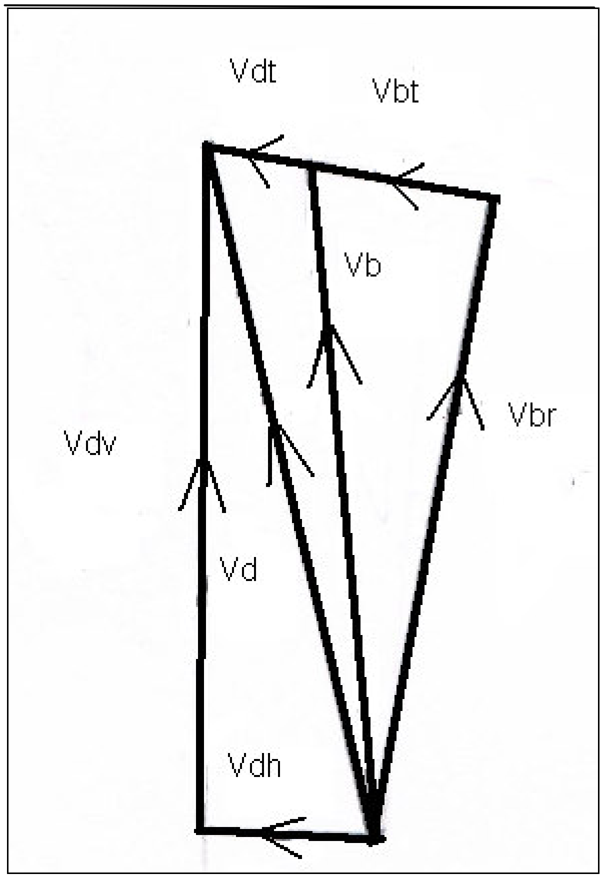


Figure 6: kinematic diagram of the suspension

The suspension ratio, R, can be calculated from the formula R = V_{dv}/V_{br} .

Based on the analysis from the kinematics diagram, V_{dv} = 300mm/s, V_{br} = 260mm/s

Thus, R = 300mm/s / 260mm/s

= 1.154

The Scrub to Bump ratio = V_{dh}/V_{dv}

= 300mm/s / 90mm/s

= 3.33

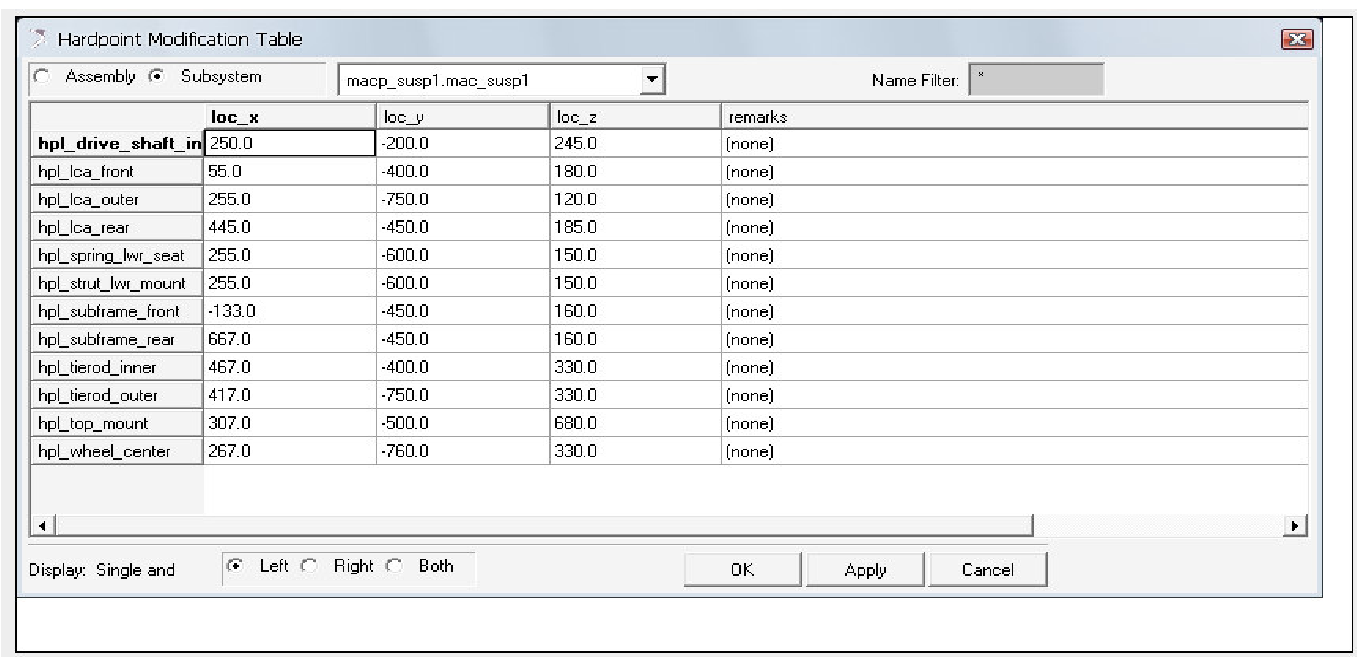
The value of the suspension ratio and scrub to bump ratio might have contain error and will be improved as we proceed further with the project.

4.3 Experimentation and Modeling

The experimentation and modeling part of this project will be conducted with the ADAMS car. So far, the progress of the modeling are still in the beginning stage as the parameters of all the hardpoints of the Myvi are yet to be obtained. The initial attempt to measure hardpoints was done and the procedure were then stopped due to some problem encountered in measuring some of the hardpoints of the front suspension which may lead to the inconsistency of the results if it's being used to simulate in the ADAMS Car. The method previously used was the string and measurement tape method but the measurement taken were not that accurate compared to the Laser method. In order have a set of accurate measurements; Perodua R&D department was contacted in order to obtain the data of the hardpoints and the progress is on hold while waiting for the reply from Perodua.

4.4 Hardpoints Measurements For Front Suspension (Macpherson)

The initial hardpoints measurements of the front Macpherson suspension are as shown in Figure7.



	loc_x	loc_y	loc_z	remarks
hpl_drive_shaft_in	250.0	-200.0	245.0	(none)
hpl_lca_front	55.0	-400.0	180.0	(none)
hpl_lca_outer	255.0	-750.0	120.0	(none)
hpl_lca_rear	445.0	-450.0	185.0	(none)
hpl_spring_lwr_seat	255.0	-600.0	150.0	(none)
hpl_strut_lwr_mount	255.0	-600.0	150.0	(none)
hpl_subframe_front	-133.0	-450.0	160.0	(none)
hpl_subframe_rear	667.0	-450.0	160.0	(none)
hpl_tierod_inner	467.0	-400.0	330.0	(none)
hpl_tierod_outer	417.0	-750.0	330.0	(none)
hpl_top_mount	307.0	-500.0	680.0	(none)
hpl_wheel_center	267.0	-760.0	330.0	(none)

Figure 7: Macpherson Hardpoints

These hardpoints are measured with the string and measuring tape. Due to the limitations of this method, some of the measurements might not be very accurate. Also due to the hard to reach areas, the readings of "hpl_subframe_front", "hpl_subframe_rear" and "hpl_strut_lwr_mount" are based on reasonable theoretical assumption.

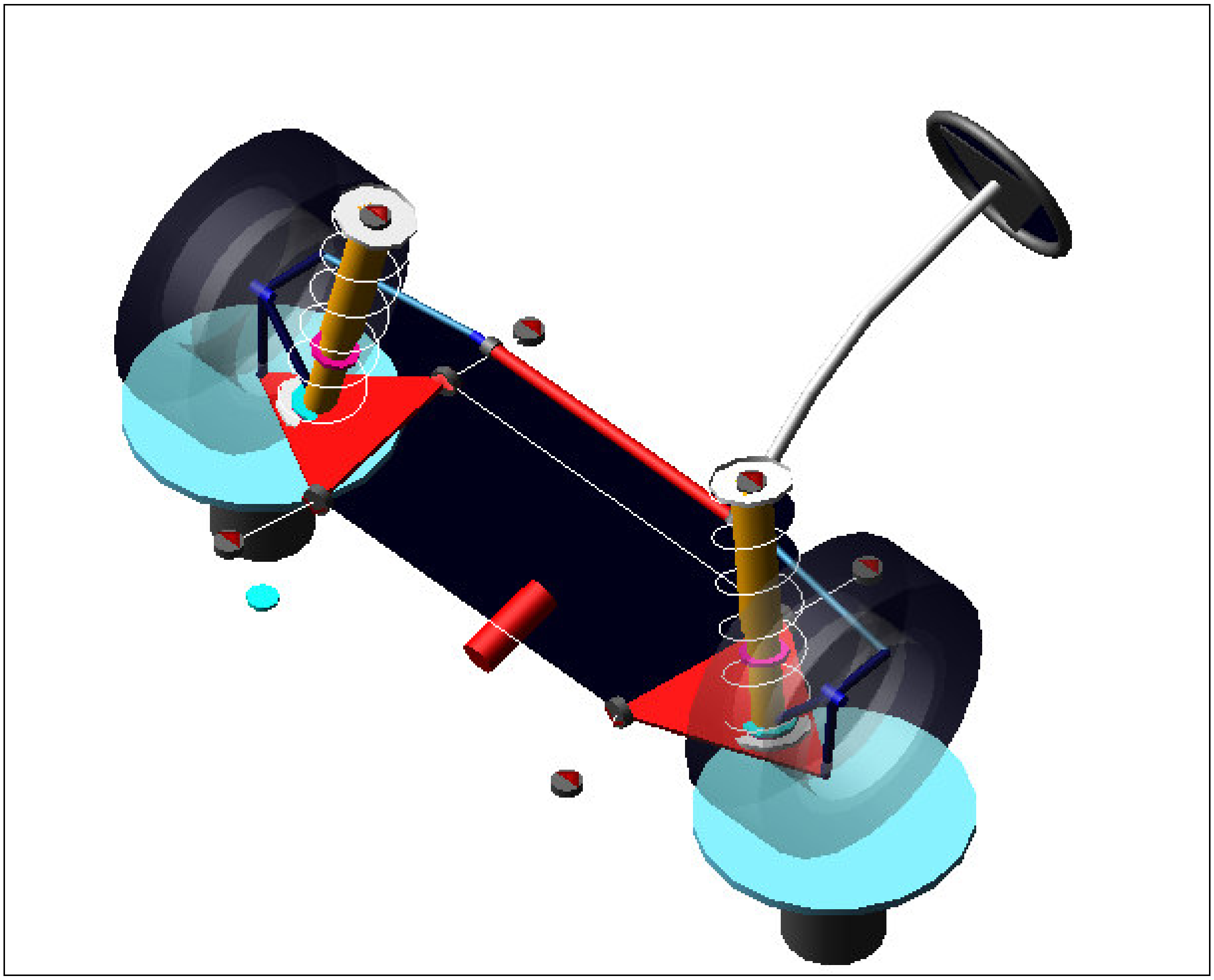
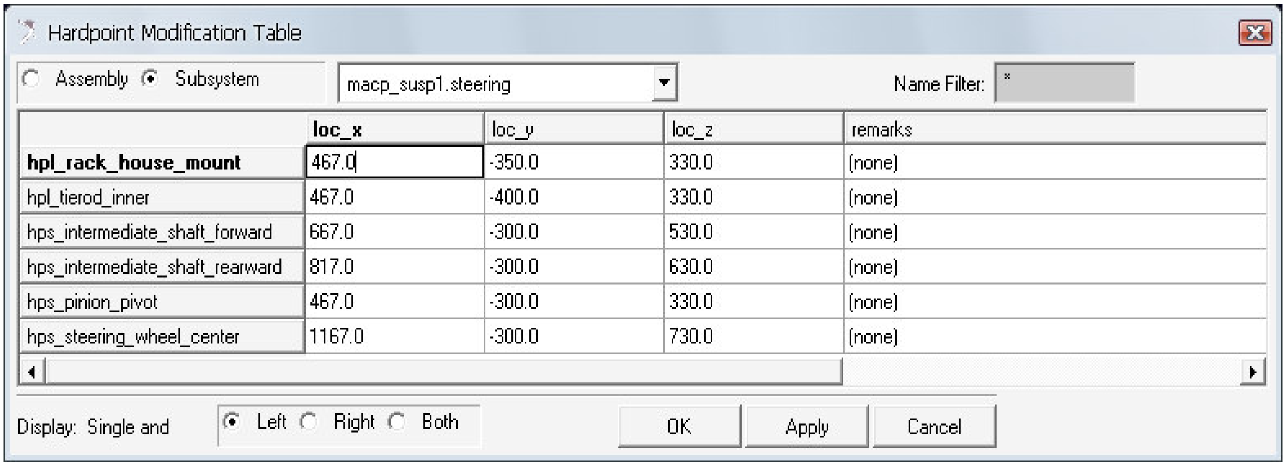


Figure 8: Modeling of the front suspension

The hardpoints of the rear torsion beam suspension were not accurate enough and needs to be measured again due to some technical problems during the previous measurement. The modeling of the front suspension system in ADAMS Car is shown in Figure 8. Since the hardpoints of the Myvi Rack & Pinion steering system cannot be obtained due to the company's confidential policy, the steering system used in this suspension assembly are based on a reasonable theoretical steering subsystem with hardpoints shown in Figure 9a.



	loc_x	loc_y	loc_z	remarks
hpl_rack_house_mount	467.0	-350.0	330.0	(none)
hpl_tierod_inner	467.0	-400.0	330.0	(none)
hps_intermediate_shaft_forward	667.0	-300.0	530.0	(none)
hps_intermediate_shaft_rearward	817.0	-300.0	630.0	(none)
hps_pinion_pivot	467.0	-300.0	330.0	(none)
hps_steering_wheel_center	1167.0	-300.0	730.0	(none)

Figure 9a: Hardpoints for Rack & Pinion Steering System

4.5 Analysis of the Break Pull Front Macpherson Suspension

Based on the model shown above, the Brake Pull analysis was simulated and the results are shown in Figure 9. The brake pull analysis was chosen to observe how the suspension reacts to the uneven braking force. In order to perform the Brake Pull analysis, the braking force must first be calculated with the following calculations:

Weight of the car = 945Kg,

Assume that the vehicle is braking at a deceleration rate of 0.5g with a 64% front and 36% rear brake ratio and a front braking force split 55% left and 45% right. These values will then be used to calculate the braking force:

Left breaking force = 945 X 0.5 X 9.81 X 0.64 X 0.55

= 1648.86 N.

Right breaking force = 945 X 0.5 X 9.81 X 0.36 X 0.45

= 1349.0 N

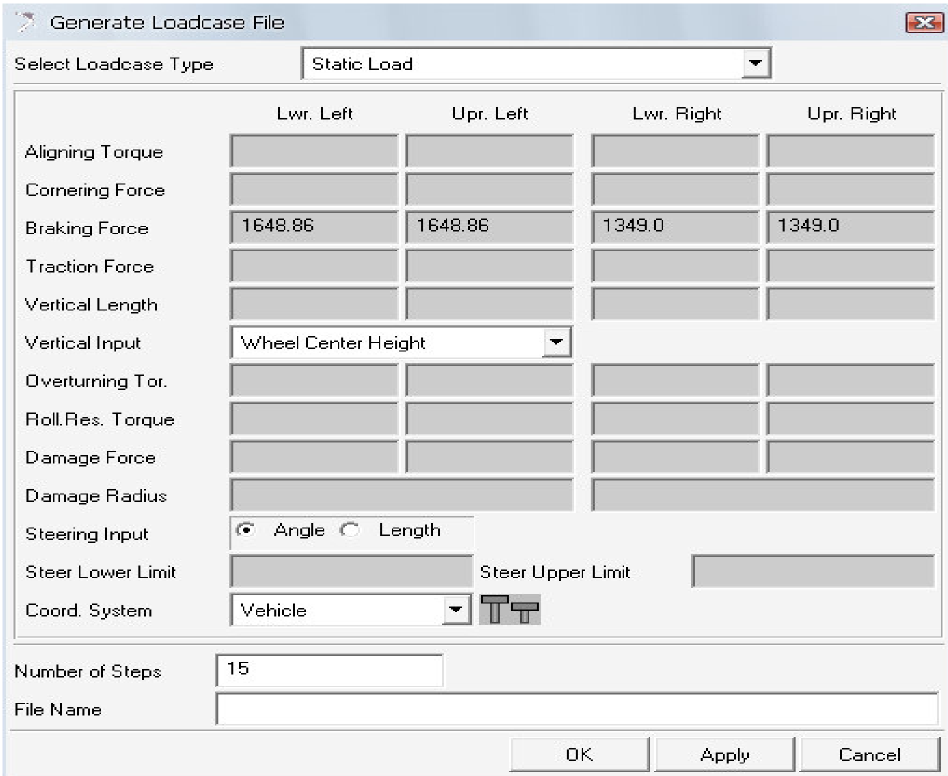


Figure 8b: Loadcase

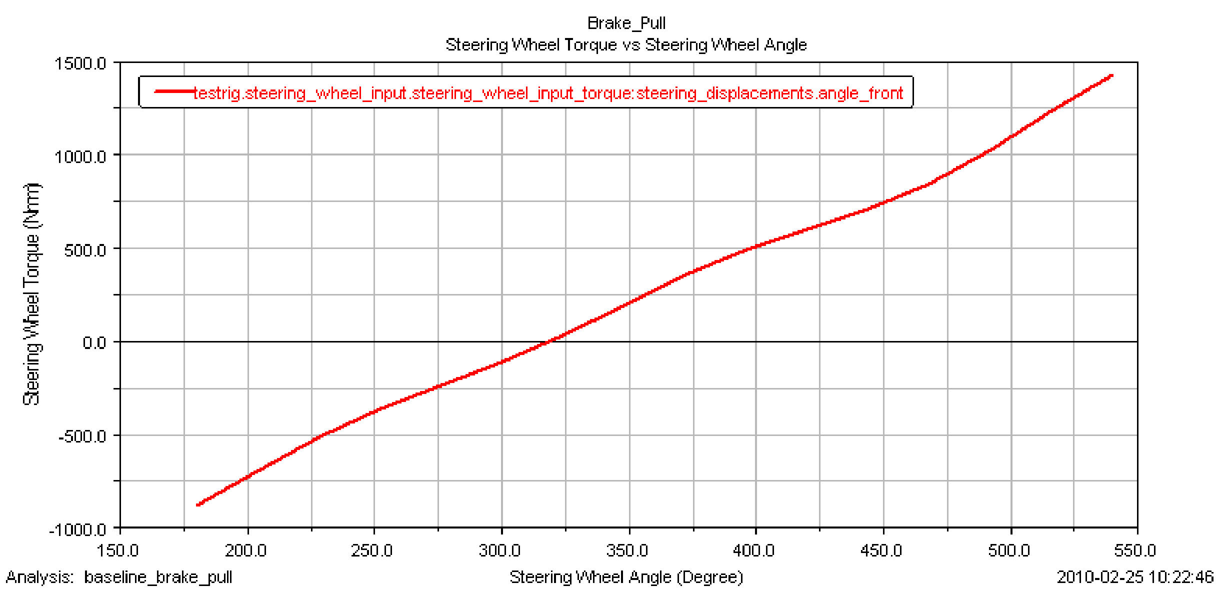
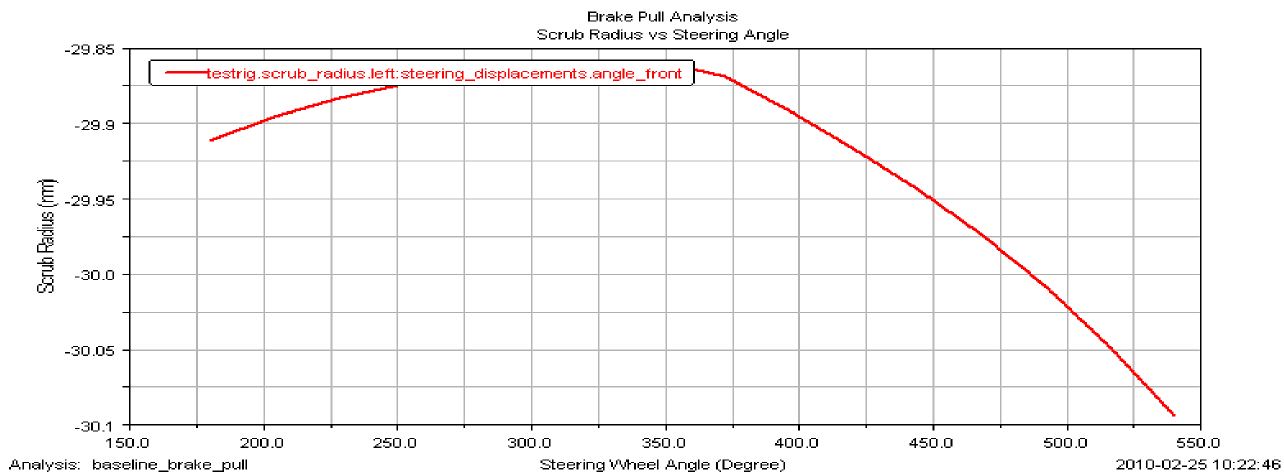


Figure 9: Steering Wheel Torque Vs Steering Wheel Angle

The plots show the torque that is generated by the test rig is applied to the steering wheel to counteract the uneven breaking force, thus holding wheel in position. The positive value of the torque means that the test rig applies a counterclockwise torque to counter the uneven braking forces that pulls the wheel clockwise, as if it's making a right turn. This result will be improved later on as more accurate parameter will be found and a better modeling of the suspension system will be conducted. From the graph in Figure 9, another analysis can be generated, which is the scrub radius vs steering angle graph, as shown in Figure 10.



<u>Figure 10: Scrub Radius Vs Steering Angle</u>

Based on the graph above, the scrub radius can be observed in the negative values. A MacPherson strut assembly typically performs well with a lot Steering Axis Inclination (SIA) and caster, a system where negative scrub works well in. Because both SAI and caster increase the amount of camber on the outside wheel when steering, the fulcrum pivot point is at a point that has more leverage, requiring less steering effort. Negative scrub also helps reduce torque steer in front wheel drive cars. Positive scrub radius works well with suspensions that use dual control arms that use less caster and SAI to optimize geometry. These findings from the results generally conformed to the review of the Myvi by car critics whereby it was complimented for its easy of steering and maneuvering.

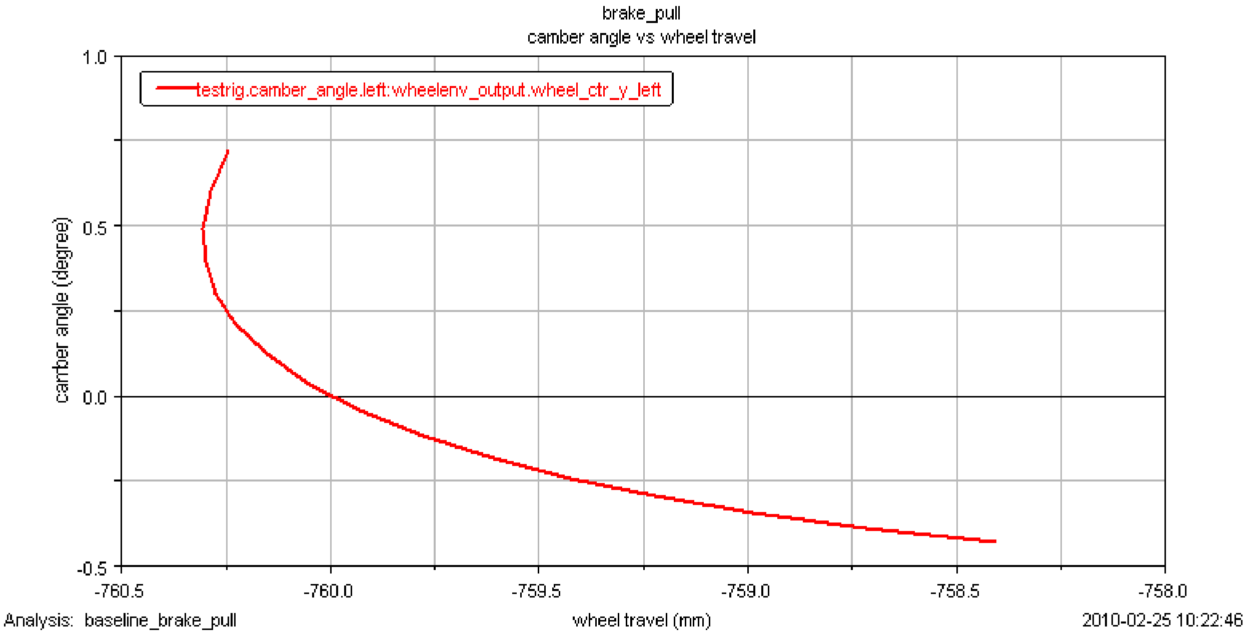


Figure 11: Camber Angle vs Vertical Wheel Travel

Based on the brake pull analysis again, the camber angle vs. wheel travel graph can be plotted and the camber angle doesn't change much with respect to the distance of the wheel's vertical movement. These results however, can still be improved later on in the investigation where more accurate parameters are yet to be found. The toe angle vs wheel travel graph was also generated from the brake pull analysis (Figure 12), but the result still needs to be improved as the graph was out of shape

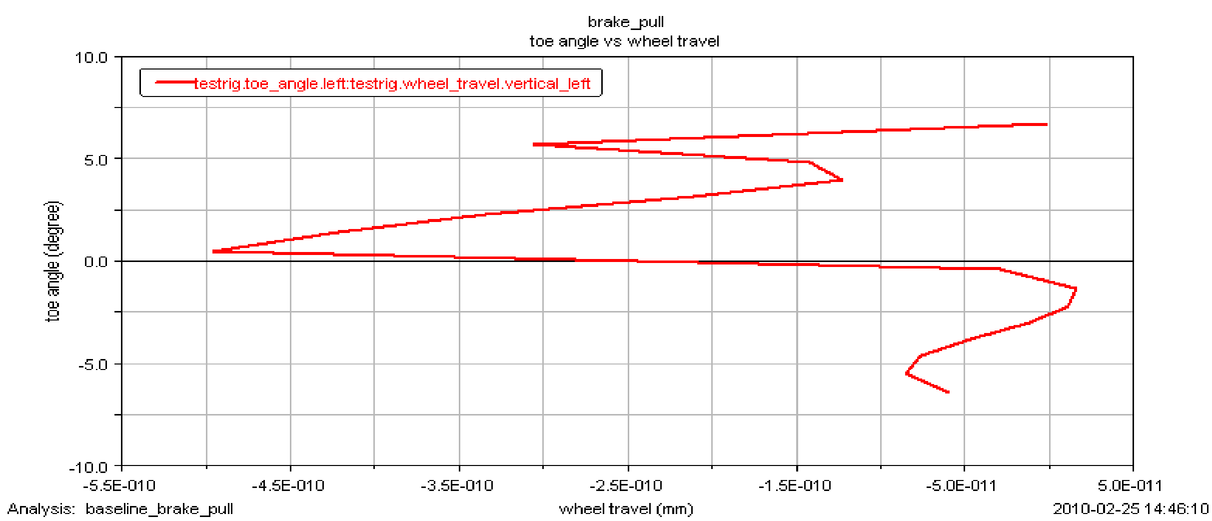


Figure12: Toe Angle Vs Wheel Travel

4.5 Full Vehicle Assembly Analysis

A full vehicle assembly analysis had been simulated from the ADAMS Car software, based on the hard points and properties of the suspension gathered. By inserting the mass of the car, the steering ratio and all the hard points, a full assembly was simulated. Specified maneuver conditions had been chosen to be simulated in order to investigate the aspect handling performance of Myvi. Following are the maneuver conditions being simulated:

a) ISO Lane Change.

b) Single Lane Change.

c) Step Steer.

d) Straight line Acceleration.

e) Braking.

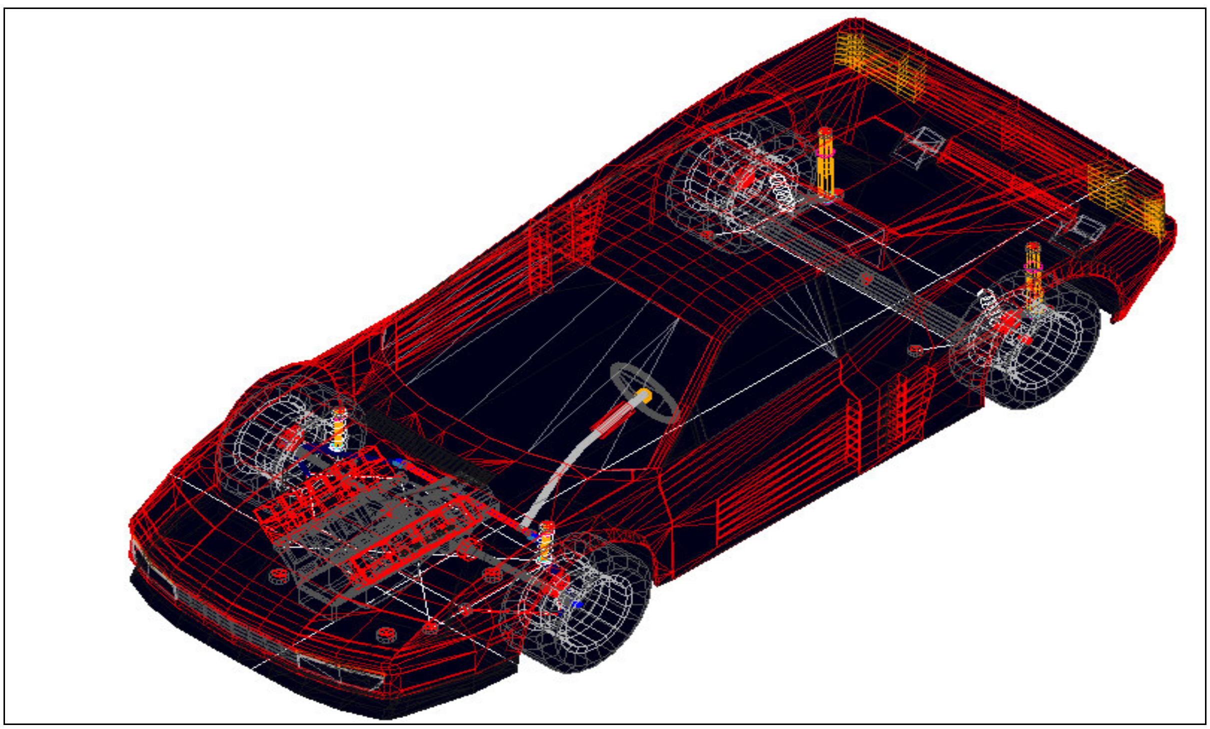


Figure 13: Full Vehicle Assembly

4.5.1 Straight Line Acceleration

The analysis of the straight line acceleration is to monitor the stability of the car as it accelerates down the stretch. The plot below shows the corresponding parameters that need to be monitored.

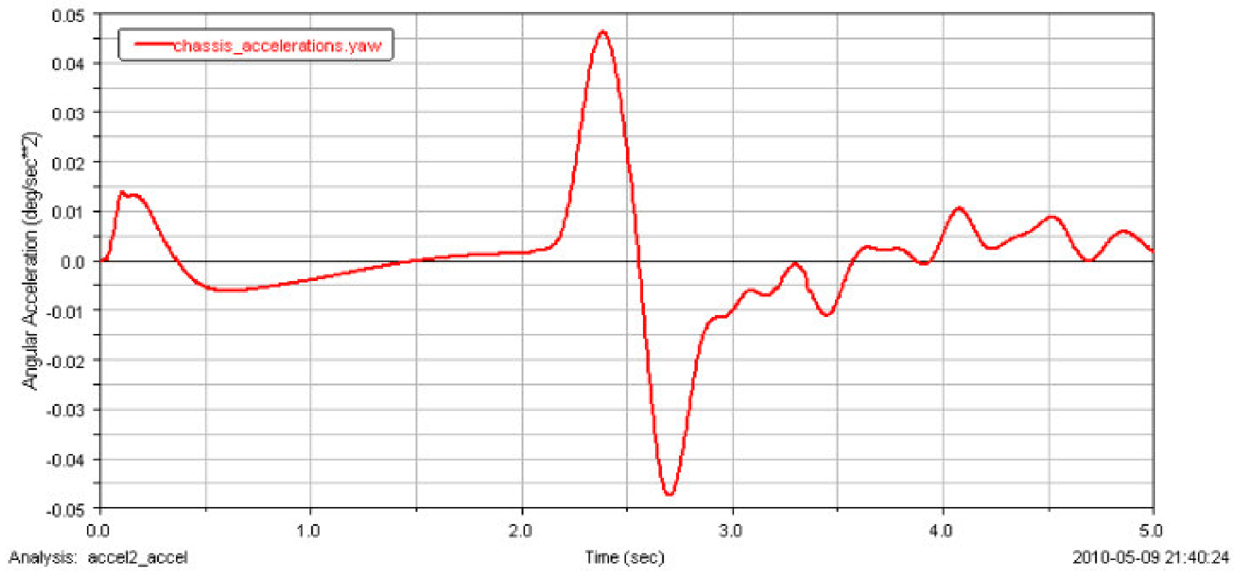


Figure 14: Yaw Angle Behavior.

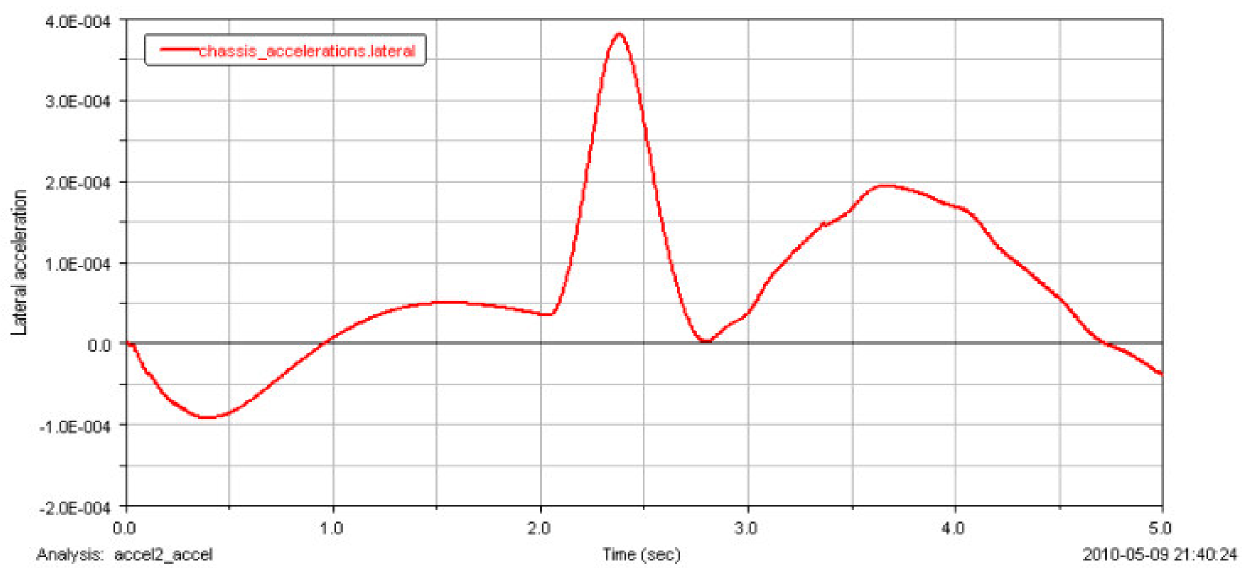


Figure 15: Lateral Acceleration

Based on the plot of Figure 14 and Figure 15, it can be observed that the yaw angle does not change much with respect to the accelerating mode. This shows that the Myvi is very stable during accelerations and the lateral acceleration further proved that the Myvi has very minimal side acceleration, which further justified the results in the yaw angle behavior plot. The parameters used are as shown in Figure 16.

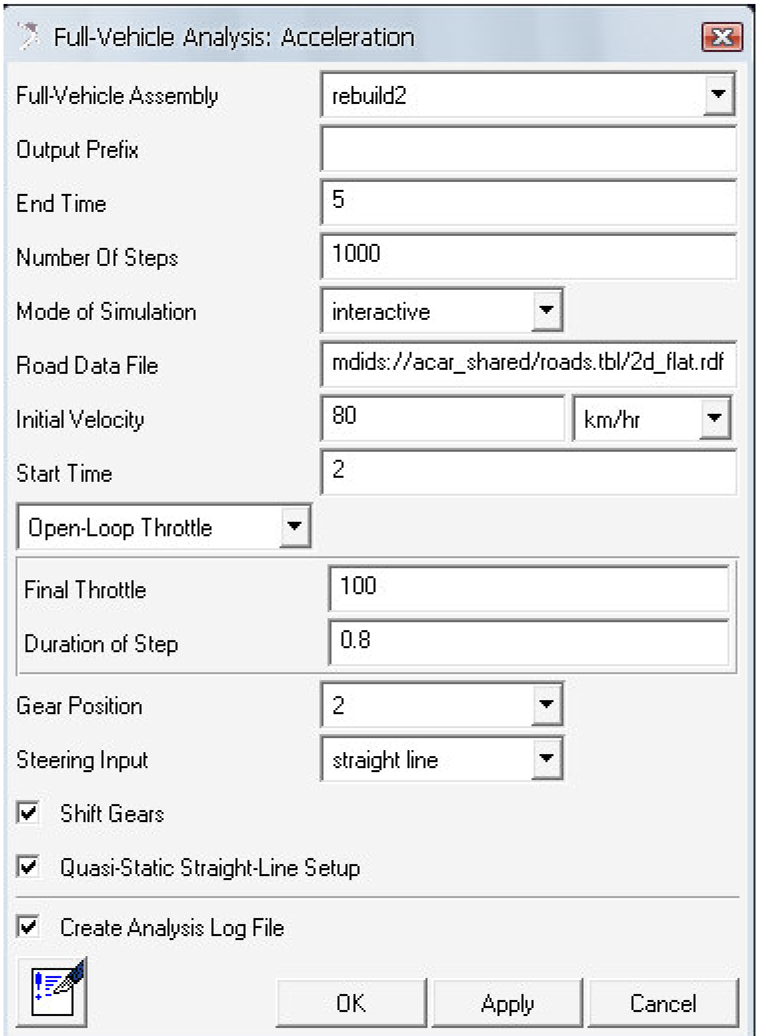


Figure 16: Parameters

4.5.2 Braking Analysis

Braking Analysis was simulated to investigate the behavior of Myvi during its deceleration to halt. Figures below show the plot of the parameters that will characterize the performance of Myvi.

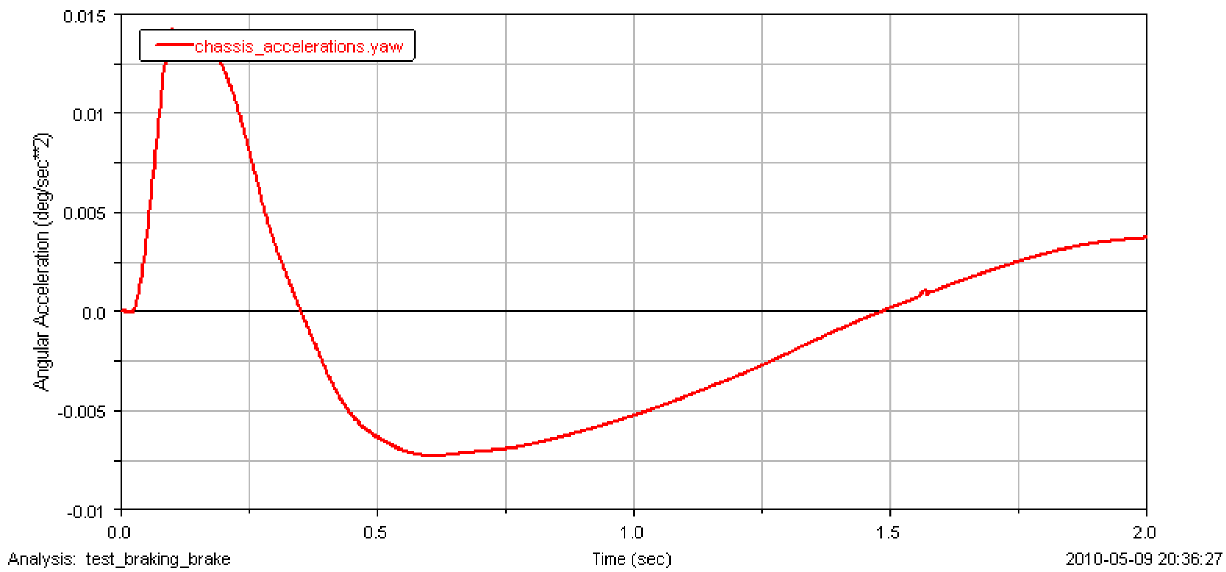


Figure 17: Braking-Yaw Angle

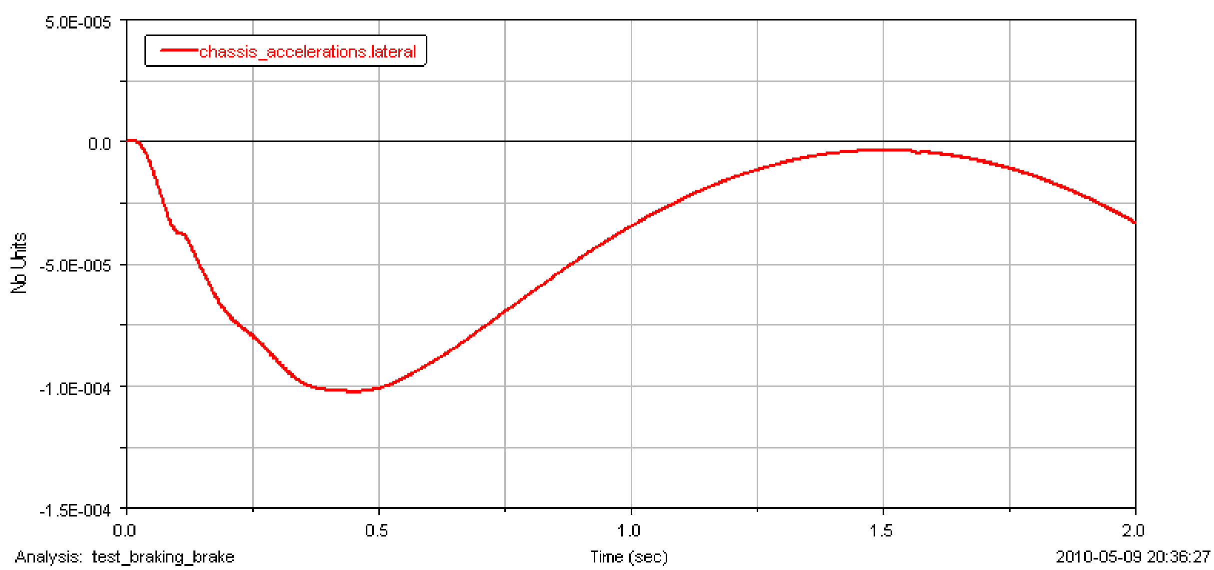


Figure 18: Braking Lateral Acceleration

According to the resulted plot, it can be summarized that the Myvi brakes well too. The yaw angle does not change much along the braking process and this shows that Myvi is very stable during braking. The lateral acceleration plot show in Figure 18 further reinforce this statement as the observed lateral acceleration was very small throughout the braking period.

4.5.3 ISO Lane Change

The ISO lane change simulates overtaking maneuvering condition the vehicle as it change lanes. The plot of the results is shown in the following.

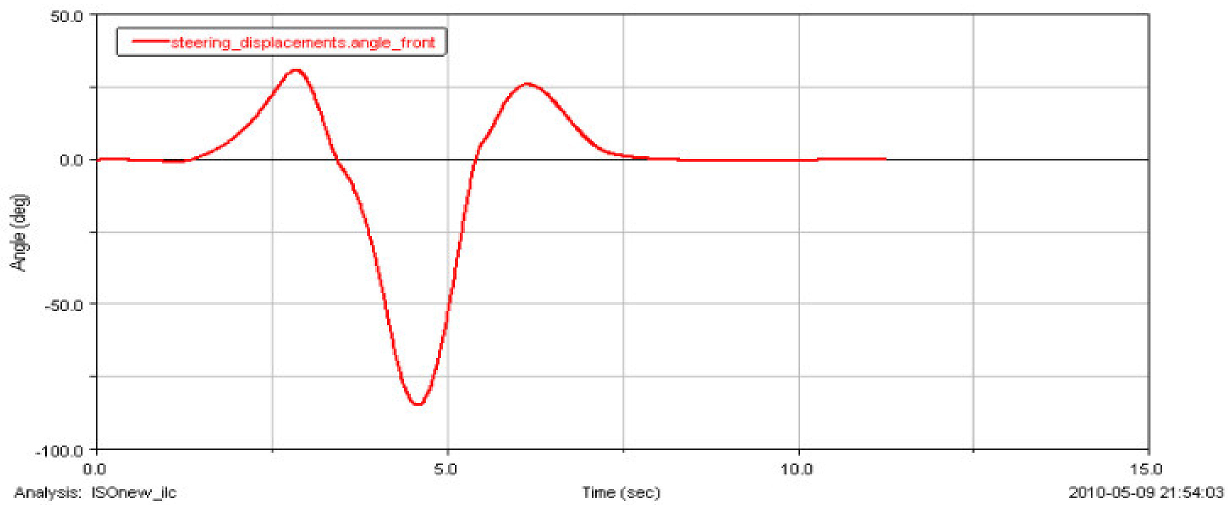


Figure 19: Steering Angle

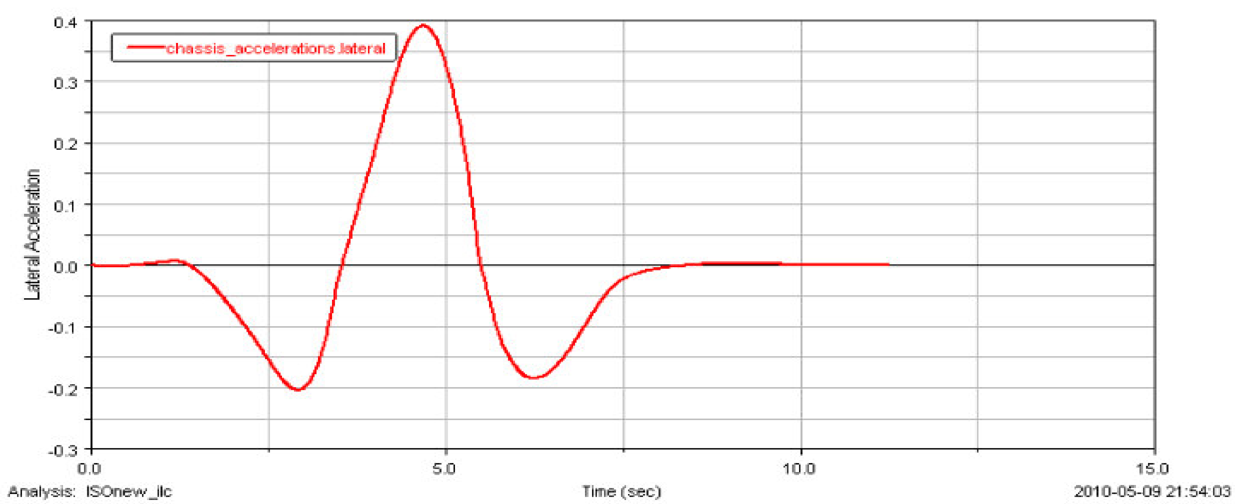


Figure 20: Lateral Acceleration during ISO Lane Change

Based on the plot in figure 19 and 20, it can be observed that the Myvi's suspension handles well during maneuvering. The plot in figure 19 shows that the steering behavior acts smoothly and exactly the same as the maneuvering conditions as the change in the steering angle value in the plot shows that the vehicle is changing direction of its drive. The same goes to the lateral acceleration as it behaves well under the ISO lane change condition where then change in the lateral acceleration in the plot is totally reasonable with the movement of the vehicle under ISO lane change condition. Following are the parameters used in this simulation.

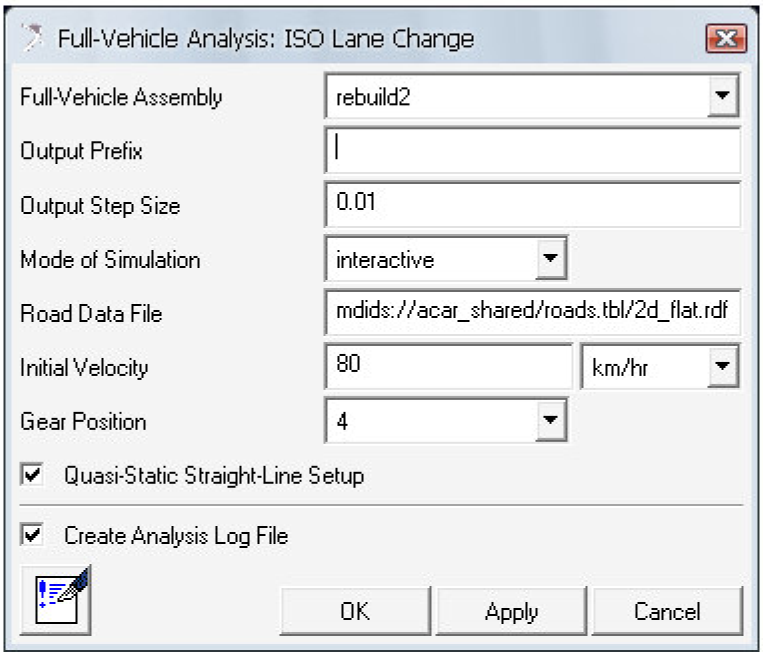


Figure 21: Parameters used

3.5.4 Single Lane Change.

Single lane change is another effective method to monitor the handling performance of a vehicle. The results of this simulation are plotted as follow.

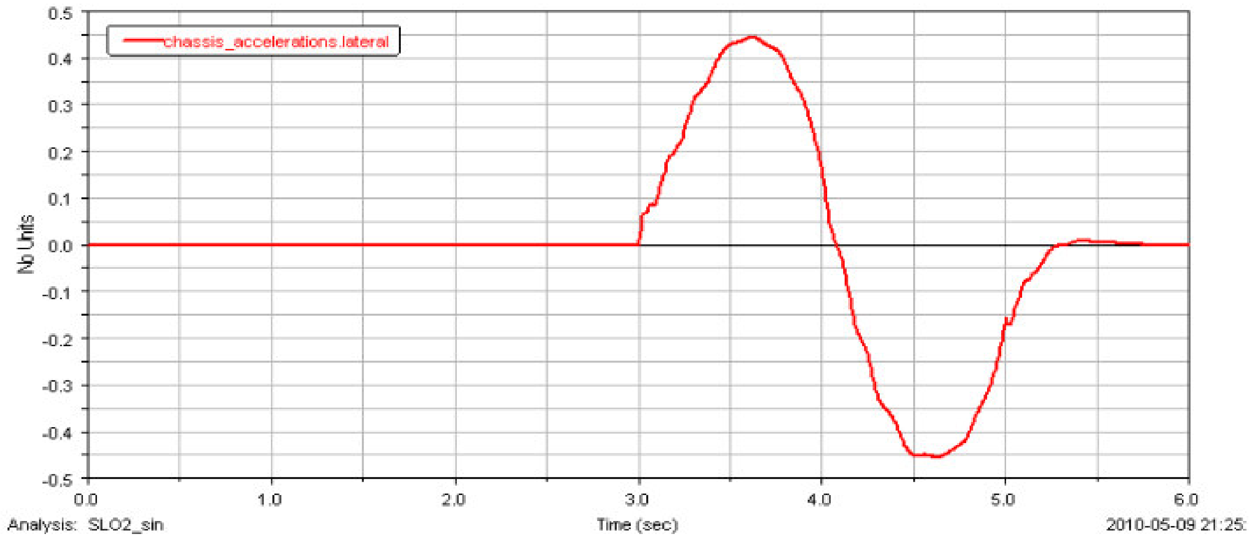


Figure 22: Lateral Acceleration for Single Lane Change

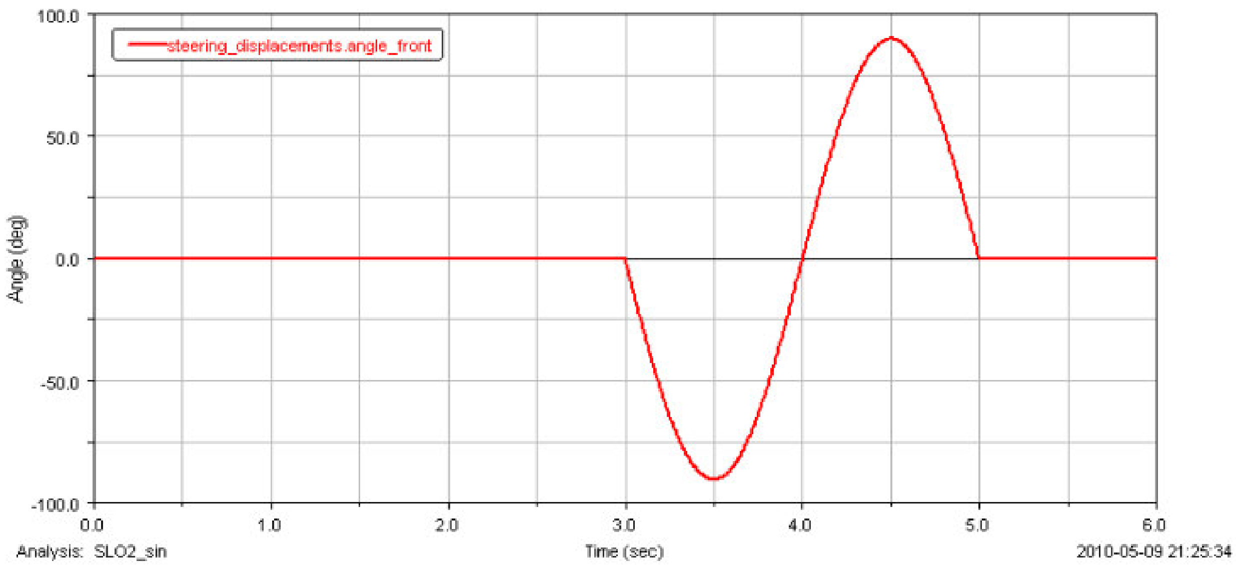


Figure 23: Steering Angle for Single Lane Change

Single Lane Change Maneuver condition is a simpler version of ISO Lane Change. The vehicle simply does not change back to its previous lane after it had changed lane. Based on the graph above, it can be observed that the Myvi is doing well both in steering and chassis stability as figure 23 shows that the handling is very responsive to the maneuver conditions where and the chassis lateral accelerations act reasonably and there's no spike in the plot of Figure 22, which shows that the Myvi is very stable in this maneuver conditions.

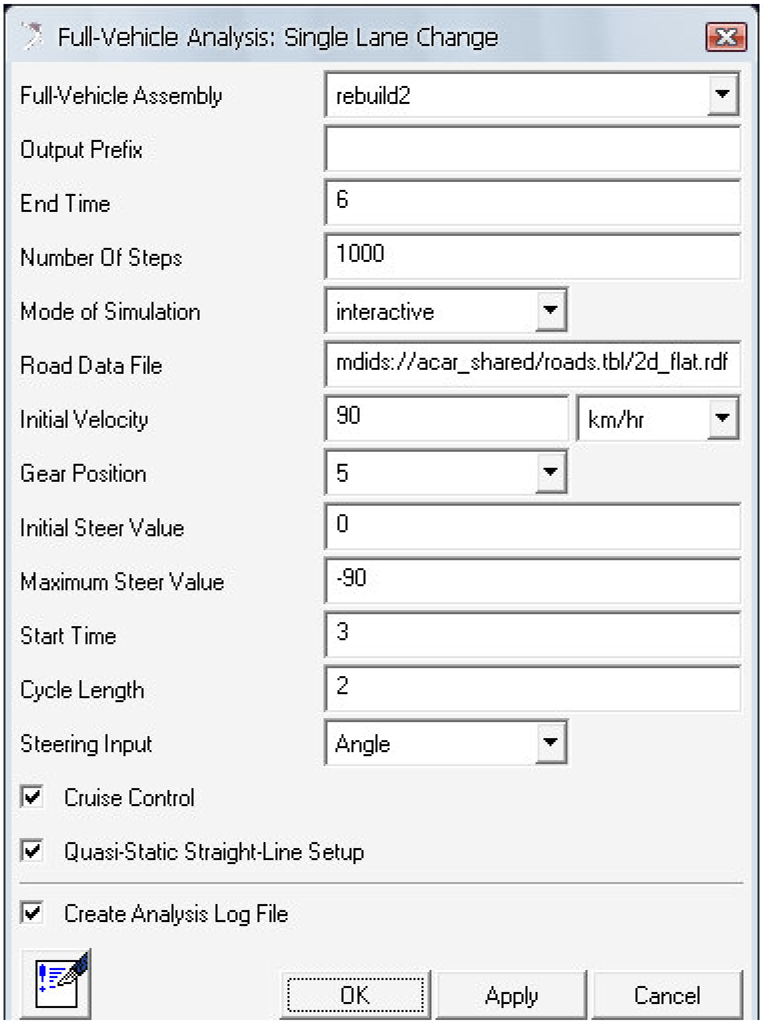


Figure 24: Parameters for SLC

4.5.5 Step Steer

The step steer simulation was used to roughly monitor the presence of understeer and oversteer conditions of Myvi under certain driving conditions. Due to the failure to run the quasi-static Constant Radius Cornering (CRC), the step steer simulation was used instead. The results will not be as detail as the CRC.

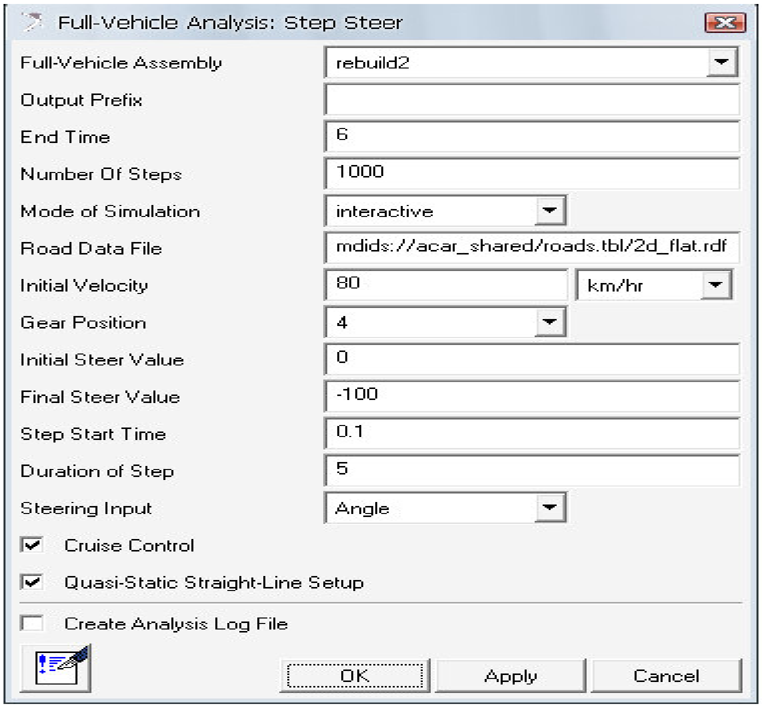


Figure 25: Parameters in Step Steer

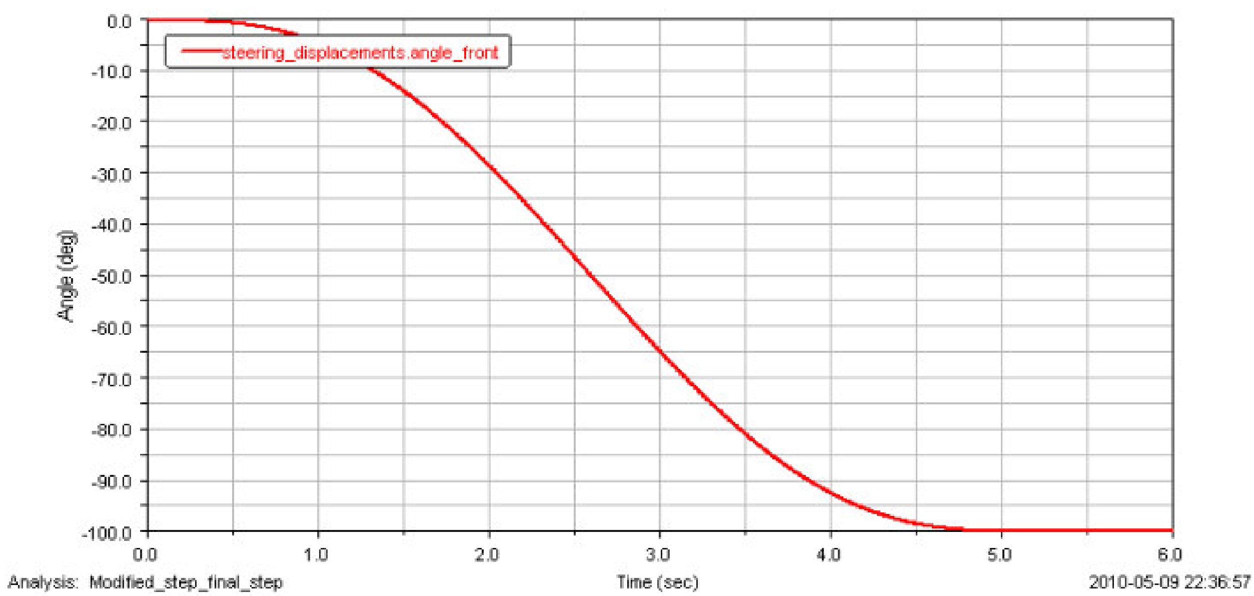


Figure 26: Steering Angle of Step Steer.

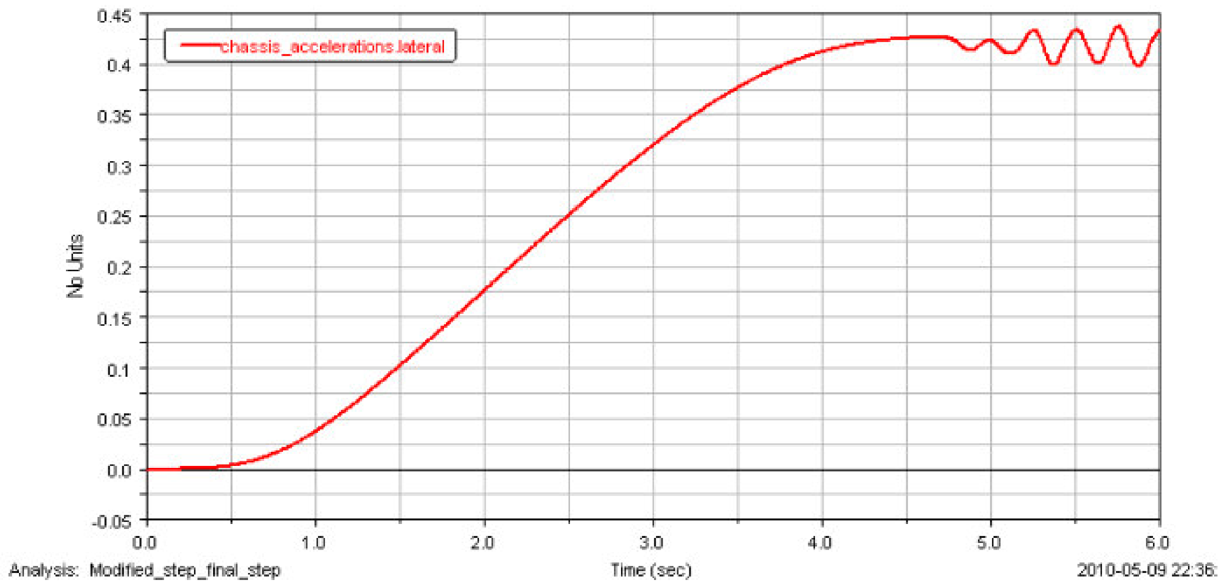


Figure 27: Lateral Acceleration of Step Steer.

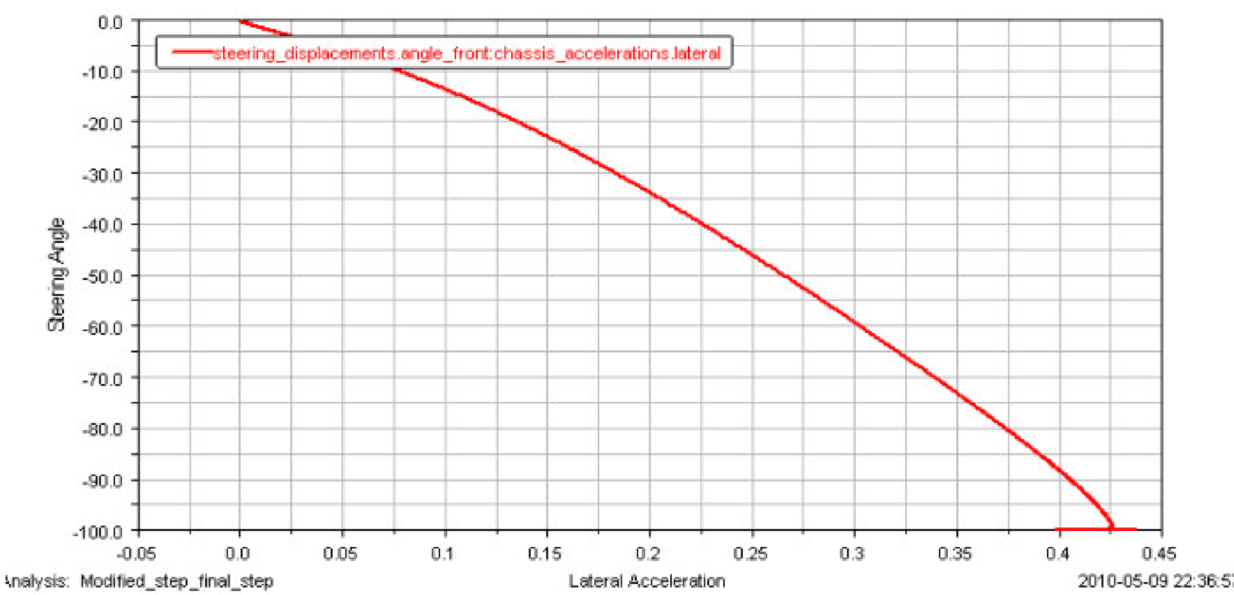


Figure 28: Lateral Acceleration vs Steering Angle.

Based on Figure 27, it can be observed that there's some inconsistency from the point of 4.6s onward of the simulation time while the other plot in Figure 26 does not encounter this problem. Based on these observation, it's obvious that the understeer presence had affected the plot of figure 27 as the there's some inconsistency in the reading. With the steering angle remained the same at that point, it's clearly shown that the steering system had not steered enough to maintain the car in stable condition which resulted in the lateral chassis acceleration inconsistency and the vehicle starts to sway. At the speed of 80KM/Hr and the steering angle of close to 100degree, it starts to understeer after 4 seconds.

CHAPTER 5: CONCLUSION

The objective of this project is to investigate the vehicle ride and handling of the Myvi using the ADAMS Car simulation software. Due to the failure to obtain certain significant parameters regarding the ride simulations, the investigation for ride failed to be carried out. Based on the simulation and analysis of the performance, Myvi is fairly a practical car to be maneuvered around town and the handling of the car might not be the best but it is good enough. The Myvi is prone to understeer in certain condition.

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