UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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SENSITIVITY STUDY OF REAR SUSPENSION PROPERTIES TOWARD VEHICLE DYNAMIC CHARACTERISTIC USING ADAMS

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Automotive Technology) (Hons.)

by

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ABSTRACT

The Multi-Link Type Rear suspension study is based on Sensitivity of the suspension parameter depending on the hardpoints in order to find its effect on the performance of the vehicle static and dynamic force. The project involve in using the Multi-Body Dynamic Programs such as ADAMS Software from MSC for a better result and understanding of how the program was used in order to find the vehicle responses toward today hardpoint characteristic and effect on rear suspension. 2 K&C studies and one Full Body Analysis was made in order for the suspension to produce result that is the Parallel Wheel Travel, Opposite Wheel travel and Full Body Analysis which consist of the Multi-link rear suspension system. All suspension parameters hardpoint will be evaluated based on vehicle dynamic target for passenger car. Using the Model that was obtained for the purpose of analysis, the analysis was done by running the simulation and using the Full Factorial DOE analysis in order to obtained the result from Tier 2nd of the vehicle dynamic analysis toward the Tier 1st which later the finalization will show which of the Hardpoint was the most sensitive so that the suspension dynamic can be improvise and optimized in the end of the project.

ABSTRAK

Kajian penggantungan Multi-Link Jenis belakang berdasarkan sensitiviti parameter penggantungan itu bergantung kepada tenggekan untuk mencari kesannya kepada prestasi kuasa kenderaan statik dan dinamik. Projek ini melibatkan dalam menggunakan Multi-Badan Dynamic Programs seperti Perisian ADAMS dari MSC untuk keputusan yang lebih baik dan memahami bagaimana program ini telah digunakan untuk mencari jawapan wahana untuk hari ini hardpoint ciri dan kesan ke atas penggantungan belakang. 2 kajian K & C dan satu Analisis badan penuh telah dibuat agar penggantungan untuk menghasilkan mengakibatkan itu adalah selari Wheel Travel, Opposite perjalanan roda dan Analisis badan penuh yang terdiri daripada sistem suspensi belakang Multi-link. Semua parameter penggantungan hardpoint akan dinilai berdasarkan sasaran dinamik kenderaan untuk kereta penumpang. Menggunakan Model yang telah diperolehi bagi tujuan analisis, analisis yang telah dilakukan dengan menjalankan simulasi dan menggunakan analisis Penuh Faktoran JAS untuk mendapat keputusan dari Tier-2 analisis dinamik kenderaan ke arah 1 Tier yang kemudian peringkat akhir akan menunjukkan yang mana satu di Hardpoint adalah yang paling sensitif supaya dinamik penggantungan itu boleh menambah baik dan dioptimumkan dalam akhir projek.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

LCA(I)	Lower Control Arm Inner
LCA(O)	Lower Control Arm Outer
SL	Strut Lower
TAF	Trailing Arm Front
UCA(I)	Upper Control Arm Inner
UCA(O)	Upper Control Arm Outer
TLI	Toe Link Inner
TLO	Toe Link Outer
DOE	Design Of Experiment
K&C Analysis	Kinematic And Compliance Analysis

CHAPTER 1

INTRODUCTION

1.1 Background

The suspension system has already been made in today's industries as one of the most important system in the automotive vehicle for which each part of the vehicle will be taking the role of stability, balanced and comfort in order to prevent the vehicle from any damage during turning or on an unstable road.

As we know today, suspension is the system that was included tires, springs, the shock absorber and even the linkages that connect the vehicle toward its wheels which allow the vehicle to a motion between the suspension and the vehicle wheels.

As of today, several suspension system was already made in order to fulfil the requirement of each vehicle to move either on stable road or unstable one. Each was tested in order to reach its full potential and prevent any unwanted damage and accident to the user especially when travelling or cornering. The suspension acted as the support of the vehicle that enable them to control the understeer and prevented rollover and such on a passenger car.

The project is made in order to study the sensitivity of the Multi Link type of rear suspension parameter toward the vehicle dynamic performance in which case we need to understand how the characteristic of the Multi Link rear suspension type and know how the vehicle dynamic tuning characteristic work using Adams/car by performing K&C and Full Vehicle Tuning. Performing design of experiment analysis on the target in order to find the hard point of and study it affect toward vehicle dynamic characteristic

1.2 Problem Statement

The Problem with today suspension system is that when you wanted to modified the suspension of a vehicle, the effect may differ as each part of the suspension system have different characteristic and tuning it may cause a different result and may causes a degraded performance instead.

A lot of suspension parameter to tune up in order to get the most optimize vehicle dynamic performance are really hard as today suspension such as a Multi-Link suspension system Hardpoints were independent. The changes of one part doesn't affect the change of another making it difficult for the parameters to be identified for tuning and modification.

1.3 Objective

The Objective of this project is to:

a) Perform a sensitivity analysis on rear suspension Multi-link Hardpoints by using the program ADAMS/CARS and ADAMS INSIGHT

b) To obtain the Tier 2 Target when doing K&C Analysis that consist of its dynamic characteristic. The target is to understand how sensitive the hardpoint adjustment was toward the suspension system

c) To obtain the Tier 1 Target when doing Full Vehicle analysis, the target will be used as guide to understand the maximum and minimum hardpoint sensitivity when performed on a full vehicle.

d) Perform Design of Experiment Toward Multi-Link Hardpoints by reducing tuning parameters based on the Vehicle Dynamic standard loadcases for example the K&C analysis and Constant Radius Cornering.

1.4 Work Scope

The project starts by assembling the suspension templates, subsystems and the assembly in ADAMS/CAR in which the Rear Suspension Model was built in Adams car environment which is used to find the hardpoints of the system. Then the K&C analysis was performing to obtain the vehicle dynamic result as the second tier target. For the next Tier Result, a full vehicle analysis was performed to obtain the parameter that exist in the system. Finally, the DOE analysis was done toward the rear suspension Multi-Link hardpoint in order to obtain the sensitivity analysis of the hardpoint toward Vehicle Dynamic Performance.

Chapter 2

Literature Review

2.0 Introduction

The automotive suspension design that determine how the aspect of today automotive engineering concern about of how each part of the vehicle required for understanding and how each effect the performance of a vehicle such as its dynamic, material and even the application of each car toward one another in the automotive industries. The Suspension system however focus on the dynamic of the vehicle in which case either Rolling, Drag and kinematic design of when a vehicle move. There are several studies was conducted before in order to find out the best design of the back suspension system based on the testing and analysis that have been done throughout the years.

2.1 Performance

The Performance of a vehicle is the main aspect of how well the design influence a vehicle for its dynamic such as Stability, Handling and drive comfort. For each changes made into the vehicle suspension system will effect on how well the vehicle could be affected by it. The dynamic value and the purpose of the study is to understand the sensitivity of the design if one of the hard points was performed and changed.

2.1.1 Influence of Suspension properties on Stability

Stability as we all know is the kinematic performance of an object to keep it stable. Each performance has their own reason as of this function to prevent the vehicle from losing it stable and in this case, a vehicle rollover which is part of the properties practiced on. There have been researched that been done on the active suspension system mainly to reduce vehicle rollover propensity which they focus on two main area of the vehicle

1) Rollover warning system

To use the prediction algorithm theory in order to determine the risk of impending rollover which they have studied using the vehicle roll angle and lateral acceleration as their inputs. The system then uses a warning signal to warn them if the inputs will have caused the vehicle to rollover and correction can be made

2) Anti – Rollover system

The anti-rollover system can be divided into four categories such as Steering, active roll-bar and differential brake but in this case they also used active suspension as one of the main part for the roll dynamic in which the vehicle design parameters can be adjusted to improve the roll dynamic of the system. The schematic of the suspension system was taken for evaluation. In this case however the properties of the suspension will be changed and evaluated.

2.1.2 Ride and Handling effected by the suspension system

The rear suspension system highly influences the vehicle variation of the car movement and how it reacted when the vehicle was moving in which case the rear suspension should be able to effect the ride and handling as it improved when the wheel can respond independently toward any kind of disturbance.

Based on the SAE of the vehicle design in which the ride and handling was performed on ADAMS to investigate the effect of Suspension design toward ride and handling of a vehicle. Just like before, the parameter that was taken and studied for was lateral acceleration, roll angle, roll rate, and yaw rate that will effect most of the vehicle system

2.2 Types of Suspension

Several suspension was used on a vehicle to fulfil the requirement of a vehicle performance depending on the type of vehicle in order to prevent it from having a rollover and able to do turning and handling on it best possible way. As we all know there are several suspension systems that already been analyse and used in today's industries but not all of them can be used efficiently for all vehicle. The type of suspension determines what the system could do and as each one have their own positive and negative value. Before people only focus on Front suspension device because rear only do the driving. But for the past decade, the rear suspension system is becoming more sophisticated and complex in order to fulfil the criteria and performance of the suspension system.

2.2.1 The Multi-Link Suspension

"MacPherson and multilink sub-systems, with good kinematics and compliance correlation, were assembled along with other required sub-systems such as powertrain, front and rear wheels, steering, and anti-roll bars to develop the full vehicle model." - 'Teahyung Shim'

The Multi link type suspension is the type of suspension that used their very own independence suspension in which case they used three or more than plus a very long longitudinal arm or more. There even a suspension handling where it provides control of the axle during the suspension cycling and when to locate the axle which is under the vehicle.

a) The arms have to Control Toe/Steer and Lateral Compliance
b) In Independent suspension, the arms have to control camber and it have to react toward tractions and braking loads which accomplished by a longitudinal link in which also control caster.
c) In Solid Axle Suspension, the upper arms may have an angle of at least 45 degrees between them in order to prevent axle from moving side to side which also help in controlling forward and backward rotation. The lower arms however control forward and backward motion which happen during acceleration and braking.

The reason why the multi-link Suspension was picked is because it allows the designer to change the ability of it kinematic and Hard points. In which case it allow the alteration of one parameters of the suspension at a time without affecting anything else

2.2.2 Torsion Beam

The Torsion Beam are the type of suspension that used twist beam. The design was simple and ingenious that both the wheel is connected by a bar that twist under duress. The torsion beam is basically cheap and easy to manufacture but in term of design, there is not much that can be tempered or altered with as it already made for solid and simple.

Plus, the performance and parameter for the design in not very well made in which the camber compliance is high, the roll stiffness is not very easy to be adjusted and the characteristic of the camber is very limited.

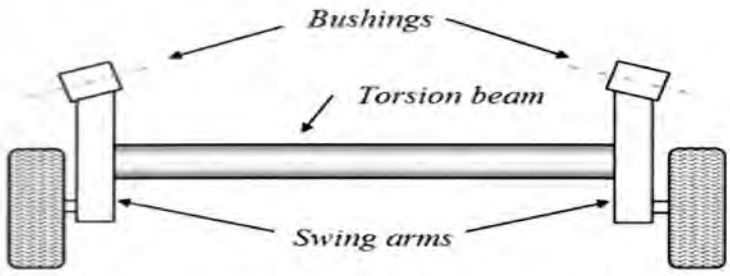

Figure 2.1 Torsion beam suspension

2.2.3 MacPherson Strut

The Type of suspension car that used the top of the telescopic damper for the upper steering pivot in which use as front and rear suspension The size of the MacPherson suspension is very compact which allows smaller chassis dimension which is perfect for a small car. Even though it was a suspension system that can be used as a rear system because for the strut. It is better suited as the front wheel drive design. Plus, the lack of chamber gain because of how the strut suspension was design resulted in causing the chassis to rolls on the suspension.

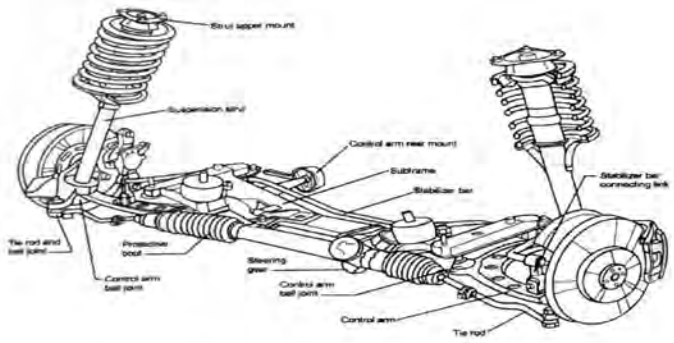

Figure 2.2 MacPherson Strut Suspensions

2.3 Hardpoints

"Suspension geometry is primarily characterized by five dominant parameters: toe, camber and roll center height for both front and rear suspensions" - 'Tachyon Shim`

The main objective of this project is to understand the sensitivity of the Hardpoint that existed in the suspension system and our ability to manipulate it in order to improve the parameter into it highest potential when use in a vehicle ADAMS was picked due to the high level of computational capacity and in addition the ability to show close simulation to the real thing. At the point when the ADAMS models for the standard and Active vehicles were constructed, the greater part of the suspension properties were made to resemble the real vehicles. The shock, the spring, and damper connections focused are precisely made inside the simulation.

The standard vehicle has various suspension parameters that were somewhat altered to simulate accurately. The most vital parameters are the spring stiffness values for the front and back, damper rebound damping and compression damping and finally the sway bar stiffness and damping. In the Dynamic suspension setup, the system replaces the standard dampers and sway bars with a numbers of chambers and

accumulators, yet holds the standard springs. The one model parameters that are held for the Kinematic vehicle are the front and back spring power, and these are almost resemble the standard vehicle. From the complex analysis of the kinematic system comes just three parameters that significantly change the properties of the vehicle which is the accumulator precharge, the system charge, and the accumulator stream/flow.

It is nearly impossible to create a nearly perfectly accurate model virtually. However, some variables in the model can be adjustable to allow for the fine tuning or as we called it, tweaking of the system hardpoints to reach the criteria wanted

2.3.1 Hardpoint Sensitivity

Each hardpoint will give out a different result during a design of experiment analysis in progress in which tweaking is involve in which case the multi-link have 12 hardpoints for alteration and modification. The important hardpoints got from screening from ADAMS are then altered to create the suspension parameters that enhance vehicle roll stability. DOE is progressively utilized for distinguishing proof and advancement of outline parameters to enhance system performance, all suspension hardpoints were surveyed for their effect on suspension design based parameters in the end.

2.3.2 Fractional Factor Design

The type of DOE design that mostly be used in the analysis when tweaking the multi-link suspension system hardpoint in which case the changes in X, Y and Z axis of the hardpoint could cause a large impact toward the performance of the suspension status. After that the level of design would be change highly based on the level of importance of how much it effected by the change that was made. Based on

the statistical analysis that was done during the experiment. Data can be gain by comparing the best one out of the experiment done and locate which one is the better one.

2.3.3 Hardpoint Alteration.

A critical thought in this process is to guarantee that when one of the parameter is changed or altered, the different parameters stay unaffected and won't give any result before it was tweaked as well. Once important changes were made and seen in ADAMS by varying the suspension parameters, the level of progress is enhanced to bring about best result in the final optimization

2.4 Parameter

These are a few example in the parameter that could be changed based on the studies done by T.Shim (2010)

2.4.1 Roll Camber

The roll camber is one of the parameter taken from past studies and used for the optimization in our current sensitivity study in which the camber angle function as the one the produce cornering force that as we know today as the camber thrust. Effectively, the positive camber thrust could add more lateral force to the tire that reduced understeer which proportional to the negative camber thrust that aids understeer.

The table below explain how each of the dominant hardpoint will be effecting the Multilink suspension camber that was done by Teahyun Shim (2010)

Hardpoint	Coordinate	% Effect
ll_inner	z	25.92
ll_outer	z	24.18
ula_outer	z	15.25
ula_rear	z	11.45
ula_front	z	7.28

Table 2.1 Hardpoints affecting camber change in multilink suspension

2.4.2 Roll Steer

Based on past studies show how roll steer affect the steering motion of the car in which the outer wheel may change into a toe-in while the inner wheel will do the vice versa of the outer wheel as it went toe out which cause understeer.

Below are the hardpoint that can cause the highest effect toward the multilink suspensions in which tierod_outer will effect it the most.

Hardpoint	Coordinate	% Effect
tr_outer	z	50.44
ll_outer	z	40.54
tr_inner	z	27.08
ll_inner	z	25.18
ll_outer	x	11.47

Table 2.2 Hardpoints affecting toe change in multilink suspension