KINEMATIC STUDY OF A MACPHERSON SUSPENSION SYSTEM

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"I hereby to declare that the work is my own except for summaries and quotations which have been duly acknowledge"

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ABSTRACT

MacPherson suspension system is widely used in passenger vehicles because it can give specious engine compartment. However, the system has less favorable kinematic characteristics. Hence, this project focused on the kinematics study to appraise and optimize a Macpherson suspension system which used in a passenger car by mean of Multi-Body system approach using ADAMS/View Software. The results of this research focused on the kinematic characteristic of the vehicle. There was several output result which not archived the target such as the camber angle changed. After the optimization, the camber angle value was increased and these were influenced the vehicle ride stability and performance.

ABSTRAK

Sistem suspensi MacPherson digunakan secara meluas pada sesebuah kenderaan penumpang kerana memberikan lebih ruang enjin kepada kenderaan. Namun begitu, sistem suspensi ini mempunyai ciri-ciri kinematik yang kurang berkesan. Oleh itu, projek ini lebih memfokuskan kepada kajian kinematik bagi menilai dan meningkatkan kemampuan suspensi MacPherson dengan cara pendekatan sistem pelbagai badan dengan menggunakan simulasi ADAMS/View. Segala keputusan yang didapati daripada kajian ini adalah lebih memfokuskan kepada ciri-ciri kinematik sesebuah kenderaan. Terdapat beberapa hasil keputusan yang tidak memenuhi matlamat seperti perubahan pada sudut kamber. Selepas melakukan peningkatan kepada suspensi MacPherson, sudut kamber telah menjadi semakin besar dan seterusnya mempengaruhi prestasi serta kestabilan pemanduan sesebuah kenderaan.

TABLE OF CONTENT

CHAPTER	CONTENT		PAGE
	RECOGNITION		ii
	ACKNOWLEDGEMENT		iii
	ABSTRACT		iv
	ABSTRAK		v
	CONTENT		vi
	LIST OF TABLE		x
	LIST OF FIGURE		xi
CHAPTER I	**INTRODUCTION**		
	1.1	Research Background	1
	1.2	Problems Statement	2
	1.3	Objective	2
	1.4	Research Scope	3
	1.5	Benefits of Research	3
CHAPTER II	**LITERATURE REVIEW**		
	2.1	Introduction	4
	2.2	Previous Work of the Project	4
	2.3	MacPherson Suspension System	6

	2.3.1 Advantages	8
	2.3.2 Disadvantages	8
	2.3.3 The Relationship of Camber, Caster, Steering Axis Inclination and Pivot Radius in Front Suspension System	9
	System	
	2.3.3(a) Camber	9
	2.3.3(b) Caster	10
	2.3.3(c) Steer Angle	10
	2.3.3(d) Steering Axis Inclination	11
	2.3.3(e) Anti-Dive and Anti-Squat	12
	2.3.4 Suspension Components	13
	2.3.4(a) Coil springs	14
	2.3.4(b) Leaf springs	14
	2.3.4(c) Air Springs	15
	2.3.4(d) Torsion Bars	15
	2.3.5 Absorber and Dampers	16
	2.3.5(a) Shock-assist Absorber	17
	2.3.4(b) Air Shock System	17
	2.3.4(c) Gas-charged Shock Absorber	17
	2.3.4(d) Shock Absorber Ratio	18
	2.3.4(e) Electronically Controlled Shock Absorber	18
2.4	Kinematic Study	19
	2.4.1 Type of Joint for MacPherson Strut	20
2.5	Multi-body system (MBS) – Mse. ADAMS	21

CHAPTER III METHODOLOGY

3.1 Introduction 22
3.2 Process Flow 23
3.3 Process Flow on Literature Review and Methodology 24
3.4 Develop MBS Model Using ADAMS 25
3.4.1 Modelling 26
3.4.1.1 Schematic Diagram and MBS Model for MacPherson 27
3.4.2 Preprocessing 28
3.4.2.1 Degree of Freedom (DOF) 30
3.4.3 Analysis 30
3.4.4 Postprocessing 31

CHAPTER IV RESULTS AND DISCUSSION

4.1 Introduction 32
4.2 The Simulation Using MSe. ADAMS Software 33
4.3 Camber Angle versus Bump Movement 34
4.4 Steer Angle versus Bump Movement 35
4.5 Steering Axis Inclination versus Bump Movement 37
4.6 Ground Level Offset versus Bump Movement 39
4.7 Caster Angle versus Bump Movement 41
4.8 Wheel Recession versus Bump Movement 42
4.9 Half Track Change versus Bump Movement 44
4.10 Summary of Results 46

CHAPTER V **CONCLUSION AND RECOMMENDATION**

5.1 Conclusion 47
5.2 Recommendation 48

REFERENCES 49
BIBLIOGRAPHY 50
APENDICESS 51

LIST OF TABLES

NUMBER	TITLE	PAGE
2.1	Summary of the Links and Joints	20
3.1	The Calculation of DOF for Suspension System	30
4.1	Complete Data from the Analysis	46

LIST OF FIGURES

NUMBER	TITLE	PAGE
2.1	MacPherson Strut	6
2.2	Front View of the Characteristic Part of the Right Front Wheel	7
2.3	Camber Angle Diagram	9
2.4	Caster Angle Diagram	10
2.5	Positive Steer Diagram	11
2.6	Steering Axis Inclination	12
2.7	Coil Springs Type	14
2.8	Air Springs Type	15
2.9	Cross Section of a Conventional Shock Absorber (Source: Erjavec, (2000))	15
2.10	Cross Section of a Conventional Shock Absorber (Source: Erjavec, (2000))	16
2.11	Types of Connection and Joints for MSe. ADAMS Software	20
3.1	Simulation Process	25
3.2	Schematic Diagram for MacPherson Suspension System (Source: Blundell, (2002))	27
3.3	MBS Model for MacPherson Strut	27
3.4	MacPherson Suspension System for BMW BMW E46 318i	28
3.5	Complete MacPherson Suspension Model for BMW E46 318i Using CATIA Software	29

NUMBER	TITLE	PAGE
4.1	The Common MacPherson Suspension with all joint	33
4.2	The BMW MacPherson Suspension with all Joint	33
4.3	Camber Angle versus Bump Movement for Common MacPherson Suspension	34
4.4	Camber Angle versus Bump Movement for BMW Suspension	34
4.5	Steer Angle versus Bump Movement for Common MacPherson Suspension (Source: Knable and Nagreski (1999))	36
4.6	Steer Angle versus Bump Movement for BMW Suspension	36
4.7	Steering Axis Inclination versus Bump Movement for Common Suspension (Source: Knable and Nagreski (1999))	37
4.8	Steering Axis Inclination versus Bump Movement for BMW Suspension	38
4.9	Ground Level Offset versus Bump Movement for Common Suspension (Source: Knable and Nagreski (1999))	39
4.10	Ground Level Offset versus Bump Movement for BMW Suspension	40
4.11	Caster Angle versus Bump Movement for Common Suspension (Source: Knable and Nagreski (1999))	41
4.12	Caster Angle versus Bump Movement for BMW Suspension	41
4.13	Wheel Recession versus Bump for Movement for Common Suspension (Source: Knable and Nagreski (1999))	43
4.14	Wheel Recession versus Bump for Movement for BMW Suspension	43
4.15	Half Track Change versus Bump Movement for Common Suspension (Source: Knable and Nagreski (1999))	44
4.16	Half Track Change versus Bump Movement for BMW Suspension	45

CHAPTER 1

INTRODUCTION/RESEARCH OVERVIEW

1.1 Research Background

MacPherson suspensions are yet very popular among passenger car and this struct can be adopted for both front and rear wheel use. In their most basic form, suspensions are designed to deal with the bumps in the road to enhance the comfort of the ride. Hence, the research of MacPherson suspension is very important research and will carry out the simulation which can investigate about the kinematic characteristic and the behavior of the MacPherson suspension system.

A general approach is put forward to determine the main parameters such as caster angle, camber angle, steer angle, and many more which influence the handling of vehicle, in function of the operational factors of the system. Given, the complexity of the system it is necessary to have access the models which permit the optimization of the global design of the vehicle. In this paper also, there is put forward a kinematic development which on the basis of the characteristic of the system allows us to determine its performance and to propose operational improvement.

1.2 Problems Statement

The problem always come up is the kinematic effect from the MacPherson suspension system of the vehicle. According to Reimpall, J. et al (2001), the MacPherson suspension system has less favorable kinematic characteristics.

So, to investigate this statement, one MacPherson suspension model from BMW E46 318i will be used for the research. Thus future investigations are required if we are to answer some questions regarding to the MacPherson suspension system of the passenger vehicle.

1.3 Objective

The objectives of this proposed research project are to get the improvement of kinematic characteristics for MacPherson suspension system by using the Multi-Body System (MBS) model.

Beside that, this project also needs to carry out the analysis using the MSe. ADAMS/View Software.

1.4 Research Scope

The scope of project is:

1. Develops the Multibody system (MBS) model.
2. Carry out the analysis of MBS system by using the MSe. ADAMS/View Software.
3. Using the front suspension system model from BMW E46 318i.

1.5 Benefits of Research

From the research, there are many good benefits that can get when doing this project such as:

1. Can visualize the characteristic of suspension system graphically.
2. The geometrical analysis can be look to the optimization.
3. Know how to provide a platform for further analysis (i.e. elastokinematic)

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

The literature review is the main important part to understand what is the important information needs are. Based on this, it is easy to determine the way of research will be implement and also the related theory that has been used in previous related research. This can be done through internet, thesis, journal, and reference books. In this research, all the information is related to the MacPherson Suspension System, the Software that using on the experiment, and the kinematics theory. Beside that, there are several subtopic will be discussed on this chapter which is the previous work of the project, introduction of MacPherson suspension system, kinematic study, and the Multibody Systems (MBS) – MSe. ADAMS

2.2 Previous work of the project

In previous research, there are many researches which related to MacPherson suspension study in automotive industry. The research has been done are covered both analysis of kinematic study for the suspension system. (Daney, D. *et al.*, 2004), some exact computational methods based on interval analysis have been used for the kinematic analysis of mechanisms involved in suspension of vehicles. It points out that, among the tools recently developed to solve exactly sets of equations, some are powerful and efficient enough to analyze and solve the kinematics of such mechanisms.

Research done by (Gorder, K. V. *et al.*, 2000), was discussed about the various tools used to measure the steering and suspension properties of a vehicle. Measuring the kinematic and compliance properties of the steering and suspension systems is an important part of the vehicle development process. Some of the ways these measurements are used include confirmation of vehicle design and build, to create and correlate CAE models, and for diagnosis of steering and handling concerns. He also found that by employing the proper tools and methods, plus having a defined vehicle dynamics fingerprint process, that most issues and concerns can be successfully resolved.

Rocca, E. and Russo, R. (2002), was study about an algorithm for the kinematic analysis of a multilink suspension taking joint compliance into account is presented. The analysis can be profitably used in an identification procedure to determine elastokinematic parameters starting from experimental data. The proposed identification algorithm is based on the solution of a typical non-linear least-squares problem. In order to test the feasibility of this procedure, a multilink suspension, modelled by a multibody dynamics code, is employed as the experimental data source. Some joint stiffness values are determined to provide an example of the algorithm's application.

In another research was done by (Vera, C. *et al.*, 2003) about the three-dimensional model is presented of the kinematic behavior of a McPherson-type steering suspension. A general approach is put forward to determine the main parameters such as caster, camber, steer angle, and many more which influence the handling of the vehicle, in function of the operational factors of the system. The input data are, on the one hand, the suspension and steering geometry, and on the other, the travel of the strut and the turn of steering wheel steer, which is obtained through monitoring the vehicle. The model has been applied to a standard vehicle and the validity of the results has been proven o this research.

For the last research, (Campbell, R. *et al.*, 2002) was explained about the ADAMS software tools which is widely used in the automobile industry to perform up-front analysis of vehicle characteristics from the point of view of vehicle dynamics. It is used for accident reconstruction and analysis, to understand the cause of the accident, improve the safety of the vehicle and a process that often requires a validated model. The research also was describes an alternative method to achieve a reliable and correlated vehicle model. Beside that, this will provides a description of the component properties required, the static and dynamic conditions evaluated and the correlation techniques used.

2.3 MacPherson Suspension System

The MacPherson struct is a type of car suspension system widely used in modern vehicles, named after Earl S. MacPherson who developed the design. This system currently employed in the vast majority in small and medium-sized cars. Beside that, it also can be used for both front and rear suspensions, but is usually found at the front where it provides a steering pivot (kingpin) as well as a suspension mounting for the wheel.

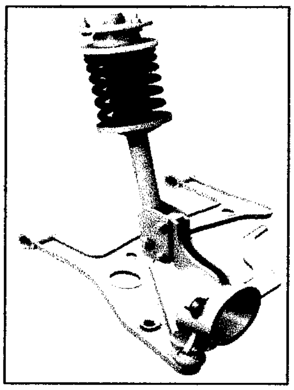

Figure 2.1: MacPherson Strut

In its commonest configuration (Fig 2.4) consist of a struct (S) rigidly connected to wheel support, or knuckle (K). The upper part of the struct is joined to the body (B) by means of a flexible union formed by an elastic element and a thrust ball bearing, which allows the rotation of the strut.

The lower part of the suspension there is a wishbone (W) or known as lower arm, which joints the knuckle to the body. The union between knuckle and the wishbone is made via spherical joints (J), the wishbone being connected to the body by means of two bushing (R1 & R2) which allows the relative rotation between both elements. The tie rod is connected to the knuckle and the damper also by means of a spherical joint in order to transmit the turn of the steering wheel to the tyre.

The strut will usually carry both the coil spring on which the body is suspended and the shock absorber, which is usually in the form of a cartridge mounted within the strut. The whole assembly is very simple and can be preassembled into a unit; also by eliminating the upper control arm, it allows for more width in the engine bay, which is useful for smaller cars, particularly with transverse oriented engines such as most front wheel drive vehicles have. For those reasons, it has become almost ubiquitous with low cost manufactures.

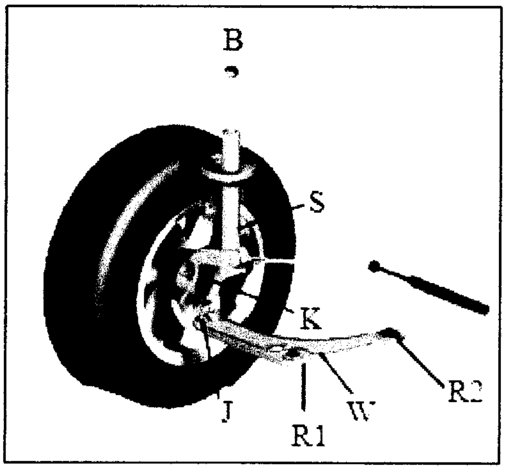

Figure 2.2.: Front View of the Characteristic Part of the Right Front Wheel

2.3.1 Advantages

The MacPherson Strut is the simpler of the suspension design. There are a few advantages which describe the MacPherson suspension system such as:

- Takes up a little less room horizontally, which allows for more room for the front drive axle to pass through the front hub.
- Allows for more passenger compartment space.
- MacPherson Struts are also relatively inexpensive compared to any of the other independent suspension types.
- Reduced unsprung weight, which not only reduces the total weight, but unsprung weight, has bigger effect on acceleration than weight inside the car.
- Increases the ride comfort exhibited by the car.
- Space of anchor points that can reduce loads, and efficient packaging.

2.3.2 Disadvantages

Not only the advantages that we can get from the MacPherson suspension system but, there are some disadvantages to this system as well.

- From a designer's viewpoint, its relatively high overall height which tends encourages a higher hood and fender line, and its relatively limited camber change during jounce.
- From the consumer level is the comparatively high cost of servicing the shock absorber.
- The problem with the amount of room available for wider wheels, without increasing the scrub radius.

2.3.3 The Relationships of Camber, Caster, Steering Axis Inclination and Pivot Radius In Front Suspension Systems

The geometric relationships of the front wheels would be relatively simple if it were not for the fact that they also steer the vehicle. Once the wheels take on the job of steering, the dynamic requirements and the angular relationships become much more complicated. With early beam axles, the steering movements were provided by the kingpin. The first kingpins were aligned perpendicular to the ground and as a result, steering movements were very simple; a wheel steered around its axis just like a door swings on a hinge. However, a suspension with a perpendicular kingpin has no self-aligning characteristics, and the slightest bump at one wheel can impart significant steering inputs. Consequently, the perpendicular kingpin was discarded very early on. Thereafter, the kingpin was attached to the axle at an angle so the swivel line projected outboard and forward toward the ground plane. The lateral tilt is known as the steering axis inclination and the longitudinal tilt is called the caster angle.

(a) Camber

Camber angle is the inclination of the wheel axis in relation to the road surface in the vertical plane. If the wheel leans out at the top, away from the vehicle, it has a positive camber angle while when the wheel leans inward, it has a negative camber angle.

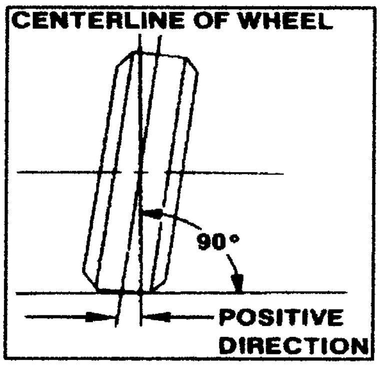

Figure 2.3: Camber Angle Diagram

(b) Caster

Caster angle introduces a new element. The caster angle refers to the longitudinal inclination of the steering axis. It creates a self-centering force that is somewhat different from the one created by the lateral steering axis inclination. A positive caster is established when the steering axis meets the ground ahead of the center point of the contact patch which is a point directly under the axle. Most passenger cars have a positive caster on the order of 0 to 5 degrees. A positive caster causes the wheel to trail behind the steering axis. When the vehicle is steered, the caster angle develops an opposing force that tends to steer the vehicle out of the turn.

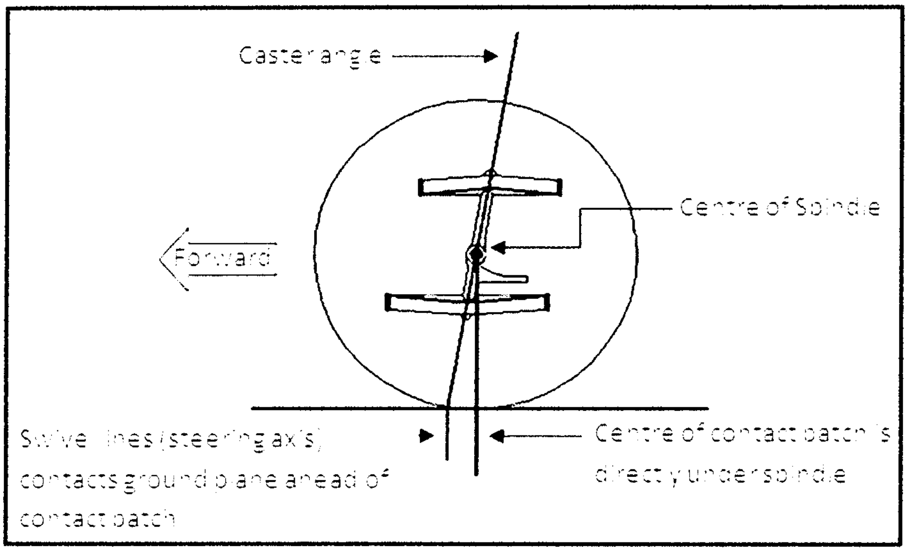

Figure 2.4: Caster Angle Diagram

(c) Steer Angle

The steer or toe angle is defined as the angle measured in the top elevation between the longitudinal axis of the vehicle and the line of intersection of wheel plane and road surface. Steer angle is measured in degrees and taken as positive if the angle between the vehicle longitudinal axis and a plane through the centre of the (steered-wheel) tire was points inward. It can also be defined as half the difference in the distance between the wheel's fronts and rear rim flange. Positive steer affects straight-running stability as well as steering and, in the case of front-wheel-drive vehicles, compensates for the resulting elastokinematic change in track. For standard-drive vehicle, toe-in is approximately 5 to 20'. For FWD vehicles, toe-out is up to 20' (to compensate for motive forces).

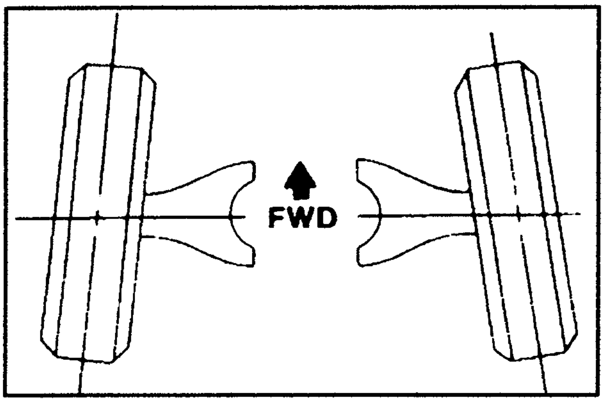

Figure 2.5: Positive Steer Diagram

(d) Steering Axis Inclination

Steering axis inclination refers to the lateral tilt of the axis around which the wheel rotates when it is steered. By leaning the steering axis inboard at the top or outboard at the bottom, the swivel-line is projected much nearer the tire centerline at ground level. That reduces directional disturbances caused when the tire encounters an obstacle. If the steering axis meets the ground inboard of the tire centerline, an obstacle will cause the wheel to steer outboard. If the steering axis projects outboard past the tire centerline, an obstacle will create a steering input toward the inside. A steering axis that meets the ground at the tire centerline eliminates the steering inputs of obstacles, but it also eliminates the "feel" of the road.

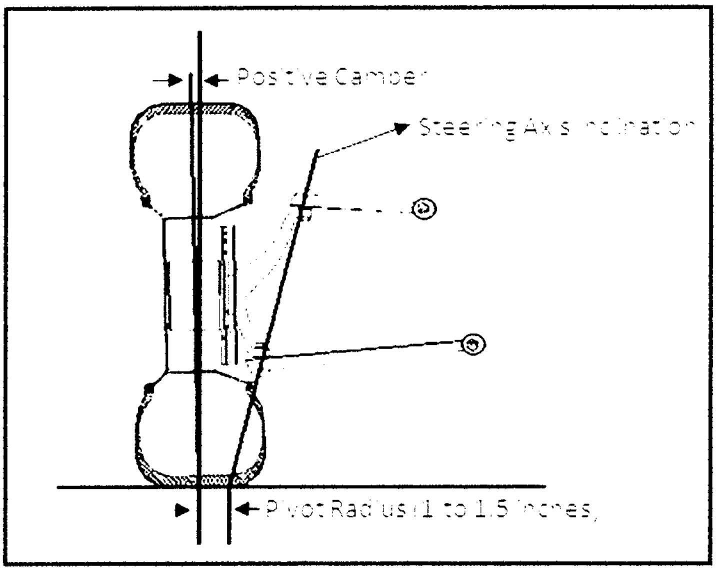

Figure 2.6: Steering Axis Inclination and Pivot Radius Diagram

(e) **Anti-dive and Anti-squat**

The other factors that contribute to the suspension behavior are Anti-dive and Anti-squat. These are expressed in terms of percentage and refer to the front diving under braking and the rear squatting under acceleration. They can be thought of as the counterparts for braking and acceleration as Roll Center Height is to cornering. The main reason for the difference is due to the different design goals between front and rear suspension, whereas suspension is usually symmetrical between the left and right of the vehicle.

Anti-dive and Anti-squat percentage are always calculated with respect to a vertical plane that intersects the vehicle's Center of Gravity. Consider Anti-dive first. Locate the front Instant Centers of the suspension from the vehicle's side view. Draw a line from the tire contact patch through the Instant Center; this is the tire force vector. Now draw a line straight down from the vehicle's center of gravity. The Anti-dive is the ratio between the heights of where the tire force vector crosses the center of gravity