Parametric Study of Ground Vehicle Suspension System

Mohamad U.H. Ruslan, Fadly J. Darsivan

Abstract--- One of the missions of automotive engineering is to reduce mass, vehicles components complexities, subsystems and systems without sacrificing expectations of the performance. Therefore, the development in suspension system of the vehicles invites many types of sus-pension system to improve the performance in stability and handling the vehicles. This study attempts to analyze the performance of two types of suspension architecture system that has been used by passengers' car. The result of this analysis such as camber, toe and caster angle will be compared to each various types of suspension system to discover the highest performance of the suspension system. Kine-matics analysis is the analysis of the motion of bodies that undergo displacement and rotation which concerns with computational modeling. Thus, software like ANSYS was used to show the association of kinematics with different types of suspension system

Keywords: Camber; caster; Ground vehicle; suspension; toe angle

1 INTRODUCTION

The first suspension that has been introduced is from horse-drawn in the 19th century. It is known as leaf spring uses a multiple layer of steel or wood. It also uses a solid beam or wood to connect the left and right rear wheel. Decade by decade, a lot of suspension systems has been designed such as Dubbonet, Gordon arm strong, Buick, double wishbone, Macpherson, multilink, trailing arm, twist axle, transverse leaf-spring and solid beam axle. Automotive suspension system can be referred as a system which holds the capability to decrease the acceleration of sprung mass continuously while minimizing the deflection of the suspension which brings improvement of the tire grip with the road surface, hence, brake, traction control as well as vehicle maneuverability can be greatly improved 1. The main role of suspension system is to maintain the balance between the road surface and tires in a maximum contact. It is also to provide the steering stability and give good handling during high speed and low speed corner. The suspension system consists of five basic components which are springs, control arm, shock absorber or dampers, tires, and wheel. It makes simultaneous performances of action with the tires, chassis, wheel bearings, brake system, bushing, joint, and steering system so that it will be safe and comfortable.

The primary function of a suspension system is for comfort, control and contact. Comfort is to provide vertical compliance so that the wheels can isolate chassis from roughness of the road. The wheels also can follow bumpy roads. For control terms, the suspension system must control forces produced by tires' lateral forces, longitudinal forces, and driving torques which is to protect the passenger and the suspension system itself 2 , 3 & 4.

Lastly for contact, the road surface must be always keep contact with the tires with minimal load variations. There are plenty of ways to increase the steering stability and handling during corner.

Plenty of researches on suspension system have been done previously. There are no suspension systems on passenger car that better in both cushion bump and stability in cornering in high speed. Therefore, each type of suspension system that used on passenger car will be studied and conducted to compare the performances.

2 SUSPENSION SYSTEM OVERVIEW

Suspension system is the system of spring combined with other devices such as shock absorber, linkage, bushing, and spindle that insulates the chassis of vehicle from shocks transmitted through the wheels. It is also causes the minimum up and down body movement when the vehicles travel over rough surfaces of road. Suspension system allows minimize the tendency to loss traction between the road surfaces and tires when vehicles to corner. It is located between the wheel and vehicles body. The purpose of suspension system are to support the weight of the vehicles, cushion bumps and holes in the road, maintain traction between the tires and the road, and to hold the wheels in alignment. Large number of rubber insulating bushing located at the inner end of the control arms, and ball joint located at the outer end of the control arms. The inner end of the lower control arm also contains large insulating bushings to prevent the noise and vibration from transferred to the support 4. There are many parameters can be calculated on suspension system such as sprung weight, unsprung weight, camber angle, caster angle, toe angle, track and steering axis inclination. One of the objectives of suspension system is to maximize lateral grip, defined lateral load as coefficient of divided by the vertical load as the weight on tires. That objective can be obtains by adding negative camber 1.

The inclination of the steering axis related to the normal line from the road surface viewed from the side of the wheel is called caster angle. The range of the caster angle usually between (-5˚ to 5˚). Toe angle represent the angle between the direction of tires are pointed and the centreline of the vehicles from top view of the vehicles. Positive toe happens when the front of both tires faced

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each other. Then, negative toe happens when front of the tires diverged each other. Excessive toe angle will cause drivability problems that because each wheel will point to other direction other than straight ahead 6.

3 CAD MODELING

CAD model of double wishbone and Macpherson suspension system can be created by using geometry data as in Table 1 and Table 2. The points in Table 1 and Table 2 refer to the location of the joints as shown in figure1 and figure 2 for double wishbone and Macpherson suspensions respectively. With this model it is suitable and convenient to performing the kinematics and dynamic analysis on the suspension system. The model also improving the variation of suspension kinematic parameters such as camber angle, caster angle, steer angle and track subjected to control actuation force. The drawing of assembly part is using Solidwork. The suspension system is not modeled by using Ansys because is complicated and time consuming compared to Solidwork. The figure 3 and figure 4 show the completed model of suspension system using Solidwork for both double wishbone suspension and Macpherson suspension respectively.All paragraphs must be justified alignment. With justified alignment, both sides of the paragraph are straight.

Table 1: Geometry data of double wishbone suspension system 7

Point	X (mm)	Y (mm)	Z (mm)
A	103	350	142
B	-127	350	128
C	-12	491	104
D	-12	589	127
E	122	345	-80
F	-108	345	-80
G	7	620	-89
H	-156	545	178
I	-15	500	540
J	-156	317	186
K	0	600	0
L	0	678	0
p	0	678	-265

Table 2: Geometry data of Macpherson suspension system 7

Point	X (mm)	Y (mm)	Z (mm)
A	125	350	-80
B	-115	350	-80
C	5	625	-90
D	-15	530	545
E	155	537	250
F	25	45	270
G	-3	545	125
H	0	670	-270
I	0	65	0
J	0	730	0

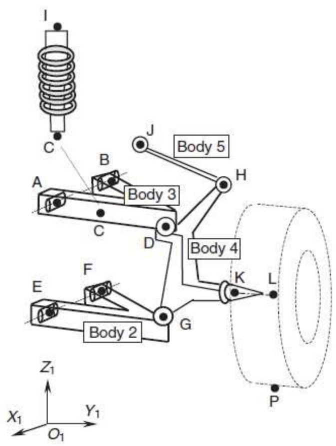

Fig. 1: Double wishbone suspension geometry [5]

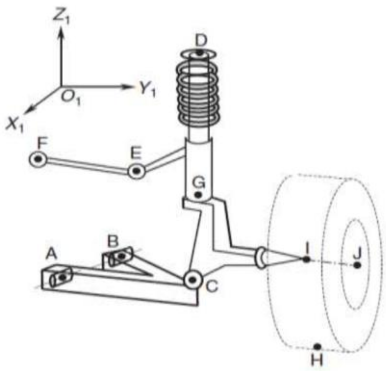

Fig. 2: Macpherson suspension geometry [5]

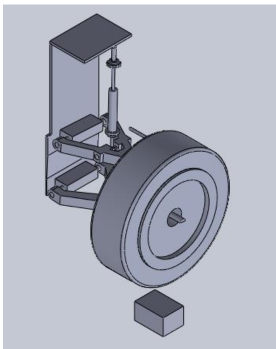

Fig. 3: Double Wishbone Suspension System

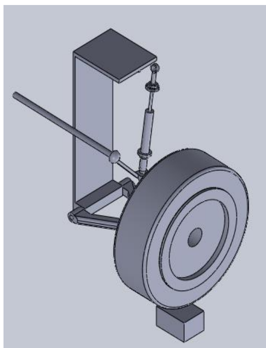

Fig. 4: Macpherson Suspension System

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4 SUSPENSION KINEMATICS ANALYSIS

The objective of the simulation conducted in this project was to find the suspension geometry parameter for double wishbone and Macpherson suspensions. The model of Macpherson and double wishbone suspension system are created by using SolidWork software. The geometry data and hard point data is used as reference [5] to create the model of suspension system. The SolidWorks file of the model will be exported to the STEP file that is because the Ansys software can use STEP file. In Ansys workbench, the connection at every links of the model need to be defines. The connection need to be chosen whether body to body or body to ground. There are many connection types which are fixed, revolute, cylindrical, translational, universal and spherical. This type of connections is used to connect every link on Macpherson and double wishbone model. After all connection are set. The model was configured to see the motion of model suspension system. For the purpose of analysis a sinusoidal wheel displacement as in figure 5 was implemented.

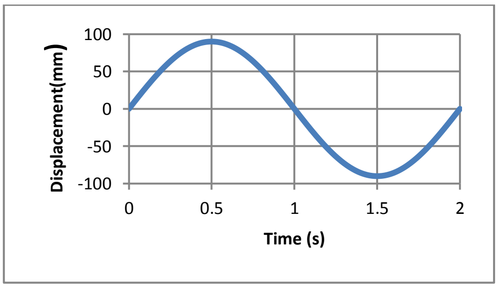

Fig. 5: Displacement versus time graph

For both double wishbone and Macpherson suspension system goes through the same simulation which is the wheel move up and down in vertical direction. The component of suspension system assumed to be rigid and frictionless. Some hard point of mechanism will be change due to the movement of the wheel. The detailed of calculation to obtain the parameter of the suspension system are explained below.

First, camber angle, γ, at final displacement can be obtained by using (1) but the x coordinates of all vector position must be equal to zero. So, the camber angle of suspension system at positive and negative in z direction displacement can be obtained. For the second angle which is steer angle, δ, can be obtained by using (2) with condition all z coordinates of all vector position must be equal to zero [5]. The camber and steer angle can be expressed as:

$$\cos\gamma = \{R_{KL}\}_1 \bullet \{R_{K'L'}\} / |R_{KL}||R_{K'L'}| \quad (1)$$

$$\cos\delta = \{R_{KL}\}_1 \bullet \{R_{K'L'}\} / |R_{KL}||R_{K'L'}| \quad (2)$$

Next, the third angle that's need to find is caster angle and it happens at z and x axis only. Set the coordinate at upper ball joint as origin because it is fixed to the chassis and new coordinate of lower ball joint can be used to find caster angle. The forth angle is steering axis inclination angle (SAI) can be obtained at y and z axis. The coordinated used is same as to find caster angle which is coordinate upper and bottom of shock absorber. Equations (3) and (4) are used to find caster angle and steering axis inclination angle can be expressed as the following:

$$\tan\Phi = x_c / z_c \quad (3)$$

$$\tan\theta = y_c / z_c \quad (4)$$

5 RESULTS AND DISCUSSION

To analyze the characteristics and to compare its performance of suspension system, two type of suspension system are tested in kinematic analysis simulation. The suspension system is simulated through motion up and down of the wheel because it is the most dominant area in terms of the loading conditions of the suspension system when the vehicle moves through bumpy road. From the Ansys workbench, new coordinates of hard point is obtained by probe position that apply on every hard point of suspension system. The Figure 1 until Figure 4 below shows comparison camber, steer, caster, and steering axis inclination angle versus displacement of wheel between the double wishbone and Macpherson suspension system respectively.

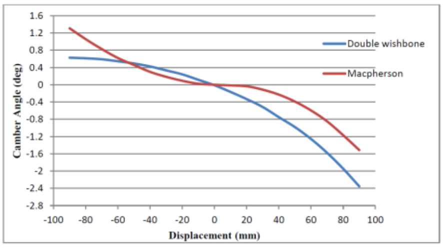

Fig. 6: Double Wishbone and Macpherson Camber Angle Versus Displacement

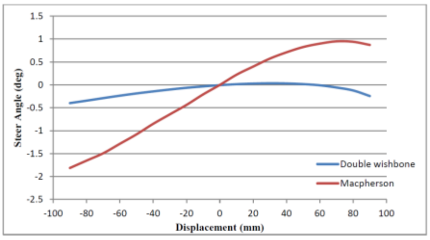

Fig. 7: Double Wishbone and Macpherson Steer Angle Versus Displacement

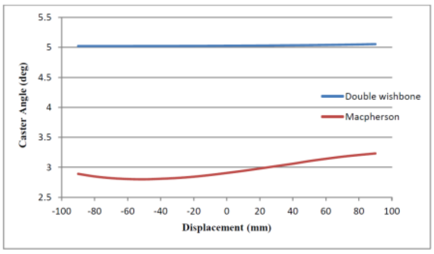

Fig. 8: Double Wishbone And Macpherson Caster Angle Versus Displacement.

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The stiffness of the spring is unaffected the kinematics of the suspension system because the kinematics is measured by applying motion to the wheel, such that system attains 90mm in bump and hole motion. Even the density of material used for modeled the suspension is also unaffected the kinematic analysis.

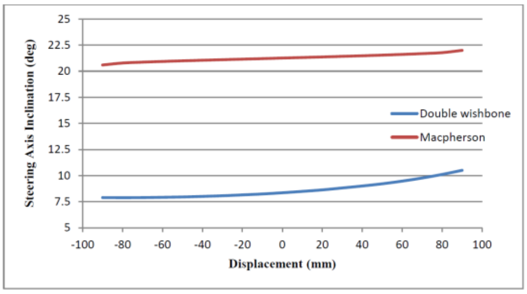

Fig. 9: Double Wishbone and Macpherson Steering Axis Inclination Angle Versus Displacement

6 CONCLUSION

The objective of this paper is to analyze and compare the characteristic of suspension system on passenger car also and to determine a suitable suspension can be used on passenger car. Due to this, kinematic analysis has been conducted to achieve this objective. From the result, both types of suspension systems namely the double wishbone suspension and the Macpherson suspension have different characteristic when subjected to vertical motion of the wheel. This is because of the dependency of the geometry and the hard points of the suspensions system. It is obvious that the plot of the front suspension start to deviate when it reach the full bounce and bump positions. It happens when bump and bounce stop producing forces that are turn back to the suspension via the bushes. Thus, the distortions that generate by reaction forces at the bushes change the geometry as shown in graph. The changes of the geometry are totally dependent on the position and orientation of the joints. Camber angle produce camber thrusts which are positive for undesteer while negative camber thrust for the lateral force. Accurate points of the joints are required as for the best performance and handling experience. From the result and discussion, it can be concluded that the double wishbone suspension architecture has less angular variation compared to the Macpherson suspension. Less variations in angular movement of the wheel will lead to better handling and vehicle stability especially in when driven at higher speed for example in motor sport. However the double wishbone has more components thus heavier compared to the Macpherson suspension.

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