Comparative Simulation studies on MacPherson Suspension System

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Abstract: *Most of automobiles these days are using two suspension systems namely: double wishbone suspension system and McPherson suspension due to their good dynamic performance and higher passenger comfort. The MacPherson strut setup is still being used on high performance cars such as the Porsche 911, several Mercedes-Benz models and lower BMW models due to its light weight, design simplicity and low manufacturing cost. This paper proposes a systematic and comprehensive development of a two-dimensional mathematical model of a McPherson suspension. The model considers not only the vertical motion of the chassis (sprung mass) but also rotation and translation for unsprung mass (wheel assembly). Furthermore, this model includes wheel mass and its moment of inertia about the longitudinal axis. The paper offers an implementation of the model using Matlab- Simulink, whose dynamics have been validated against a realistic two dimensional model developed with the Ansys software.*

Keywords: *Simulink, ANSYS, suspension, active and passive system*

I. INTRODUCTION

Some common types of independent suspensions are: Swing axle, Sliding pair, McPhersonstrut, Upper and lower A-arm (double wishbone), Multi-link suspension, Semi-trailing arm suspension, Swinging arm, Leaf springs. The McPherson strut is a type of car suspension system which uses the axis of a telescopic damper as the upper steering pivot. It is widely used in modern vehicles and named after Earlie S. MacPherson, who developed the design. MacPherson struts consist 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.

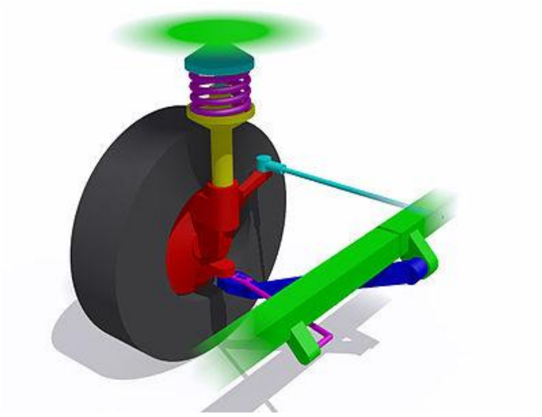

Fig. 1.1:Model of MacPherson

To be really successful, the MacPherson strut required the introduction of unibody (or monocogue) construction, because it needs a substantial vertical space and a strong top mount, which uni bodies can provide, while benefiting them by distributing stresses. 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 strut also usually has a steering arm built into the lower inner portion. 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 compartment, which is useful for smaller cars, particularly with transverse -mounted engines such as most front wheel drive vehicles have. It can be further simplified, if needed, by substituting an anti-roll bar (torsion bar) for the radius arm. For those reasons, it has become almost ubiquitous with low cost manufacturers. Furthermore, it offers an easy method to set suspension geometry.

The McPherson suspension is widely used in small and medium size vehicles due to its light weight, compact size and low cost. Fig 1.1 shows a McPherson suspension system which consists of a suspension arm or control arm plus a spring-damper assembly (strut) firmly attached to the wheel assembly. Large and systematic changes in kinematic parameters, such as camber angle and track width are a major problem in modeling and controlling this type of suspension. The quarter-car linear model is commonly used to analyze the suspension dynamic behavior. However, this model does not consider the suspension system structure, which affects significantly the system dynamic behavior. It has been shown in other research papers that two types of suspension geometries produce different responses in real systems and equivalent parameters have been proposed to improve the linear model. In the case of the McPherson suspension, its variable geometry provokes a nonlinear behavior, which can be analyzed with two dimensional linear models. This work proposes a systematic and comprehensive development of a linear two-dimensional ANSYS model of McPherson suspension. The model considers that sprung mass (chassis) moves vertically, and that the unsprungmass (wheel assembly) experiments a two-dimensional motion of rotation and translation. In addition, the model includes the wheel mass and its inertial moment about the longitudinal axis. Generalized coordinates Z_s and Z_u are used to see the transient response. The model also takes into account the geometric structure, as well as tyre damping and lateral stiffness, which have not been considered in other related works. Furthermore, the paper also describes the implementation of model using Matlab-Simulink. Simulation allows analyzing the system dynamic behavior versus road obstacles and depressions. Moreover, to validate the results, these have been compared with the realistic two-dimensional model of the McPherson suspension developed using Ansys software.

The rest of the paper is organized as follows. The brief literature review is given in section 2. In section 3 the results of simulation of Simulink model and ANSYS models are presented. Section 4 draws the conclusions.

II. Review of Literature

Survey of advanced suspension developments and related control applications can be seen [4]. The synthesis and analysis of suspension mechanisms various suspension systems are covered in [9]. All models of suspension systems are classified as active and passive systems. In passive systems are analyzed by many others with the spring and dampers [2, 6, 7]. All these studies are concentrated to see the effect of the suspension structure on equivalent suspension parameters like stiffness and damping ratios.[6].The modern Fuzzy control of semi active automotive suspensions is being studied by A. AbuKkhudair, R.muresan and S.Yang,[3].The dynamic models of MacPherson suspension are developed with all geometric parameters [1,3,7]; but all models involves non linear terms therefore the complicated mathamtical methods are required to obtain responses. In this paper two simulation models of Mac Pherson suspension developed in ANSYS and Simulink Softwares by eliminating no linearity. This will leads the solution easy with little compromise on the accuracy.

III. Simulation Results

The kinematic model of MacPherson suspension is developed in [1] and the same is shown in the Fig.3.1.

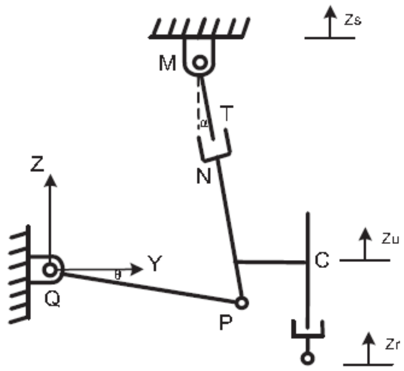

Fig.3.1:Kinematic model of MacPherson suspension

The key points are defined at Q, P, N, T, M, C as shown in Fig.3.1 and elements are generated in ANSYS software. The coordinates of these points are shown in Table.3.1. Model parameters are taken from earlier in the mathematical model [1] and shown in Table 3.2. Using the above parameters, the Ansys model is generated and transient analysis is carried out. The steps adopted for transient analysis are from the manual [10].The input considered is a square wave signal of 50mm amplitude,40s period with a phase shift of 15 sec. This disturbance is made as a road bump on which the wheel of automobile is passing over it. The response of the displacement sprung mass i.e the chasis of automobile and the response of acceleration of unsprung mass are extracted from the transient simulation studies in ANSYS. These responses are shown in Figures 3.2 and 3.3.

Table 3.1: Coordinates of key points

Key point	X coordinate(m)	Y Coordinate(m)
1	0	0
2	0.5791	-0.214
3	0.5588	0
4	0.5368	0.351
5	0.500	0.468
6	0.621	0
7	0.621	-0.351

Table 3.2: Model parameters

Particular	**Variable value**
Mass of the chassis(sprung mass) Kg	m_s=439.4
Mass of the tyre (unsprung mass)Kg	m_u=42.3
Suspension stiffness N/m	K_s=38404.0
Suspension damping Ns/m	B_s=3593.4
Tyre vertical stiffness N/m	K_t=310000.0
Tyre lateral stiffness	K_{tl}=190000.0
Tyre damping Ns/m	B_t=3100
Tyre effective radius m	R=0.3
Wheel inertia moment in x-axis Kg m^2	I_c=1.0

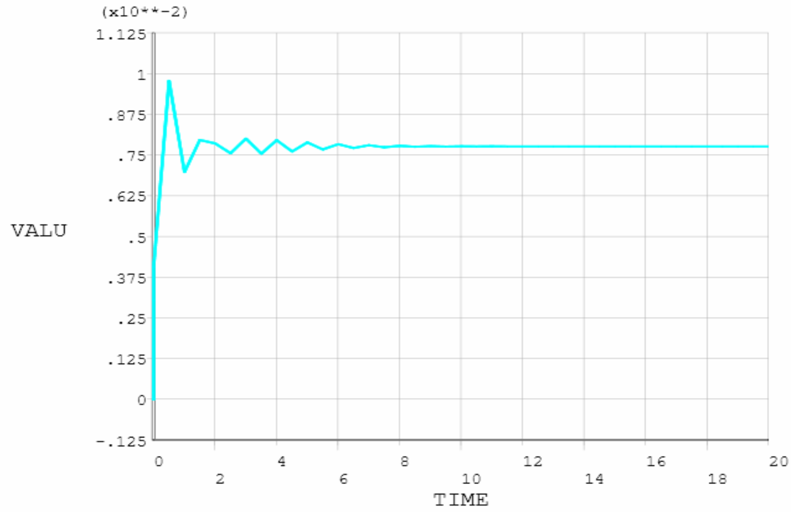

Fig.3.2: Response of displacement of chassis

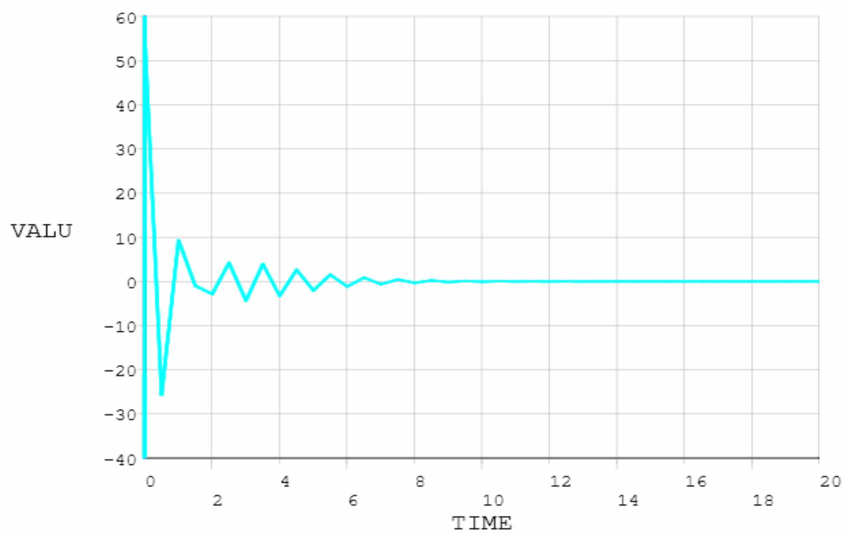

Fig.3.3 Response of Acceleration of the chassis

Now that the Simulink block diagram is completed [see Fig.3.4] based on the dynamics equations developed in the research worn in [1]. The dynamic response of the suspension system is carried out with similar disturbance generated by the road Z_r in the ANSYS Model The disturbance is modeled as a square wave signal of 50mm amplitude,40s period with a phase shift of 15 sec.

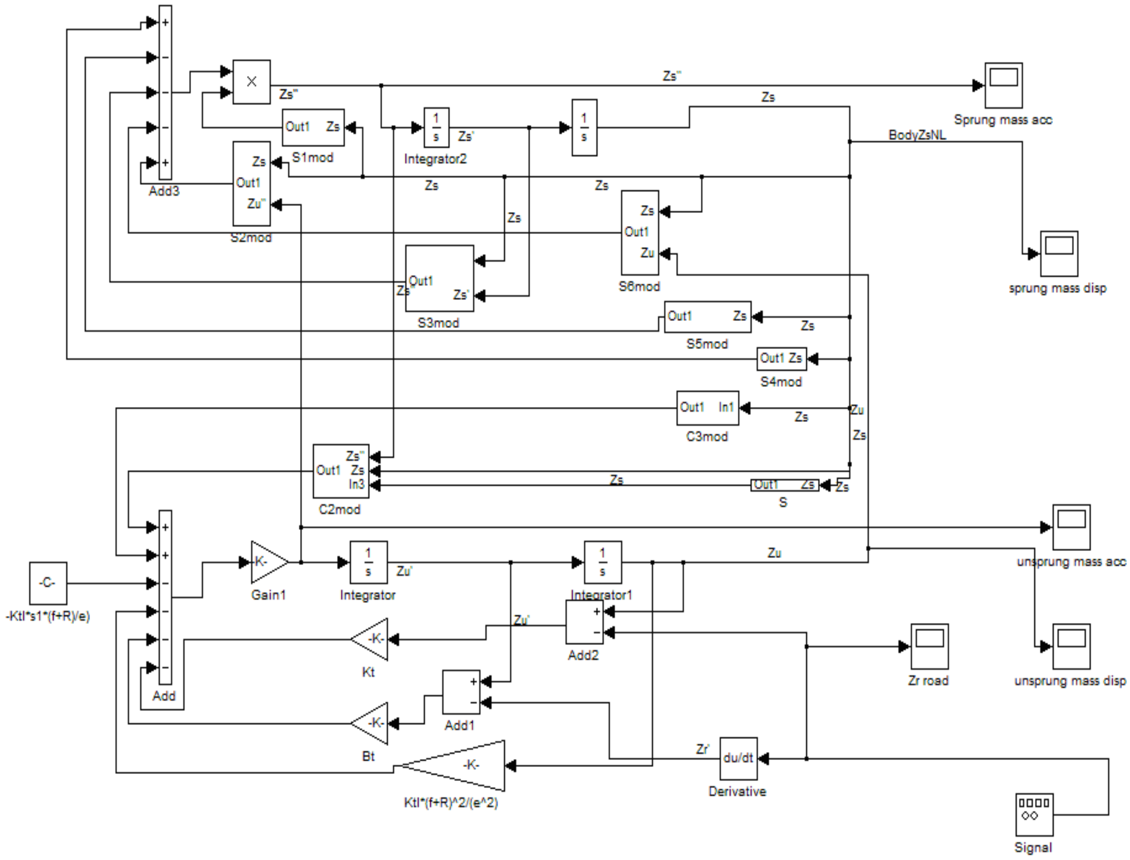

Fig.3.4: Simulink Block Diagram of Suspension System.

The response of displacement and acceleration of chassis obtained from block diagram are shown in Figures 3.5 and 3.6. The two simulation studies are showing almost same maximum values of displacement and acceleration of chassis. The acceleration experienced by the chassis is less than 10g m/s^2 .It indicates the designed MacPherson suspension giving satisfactory passenger comfortable acceleration**.**

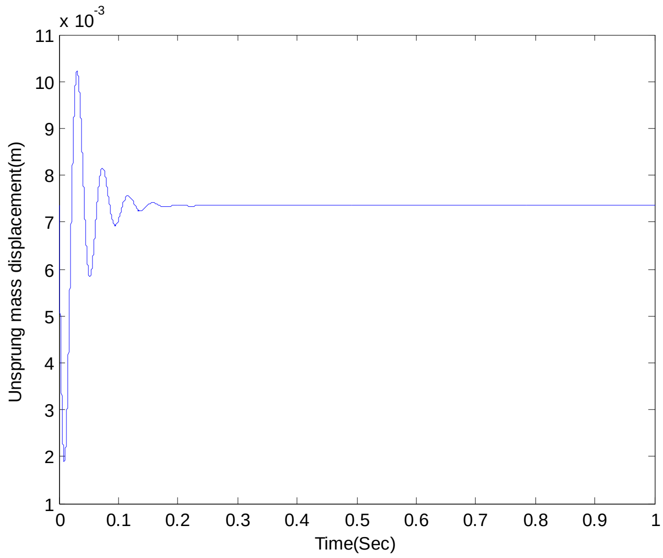

Fig.3.5: Displacement response of Chassis

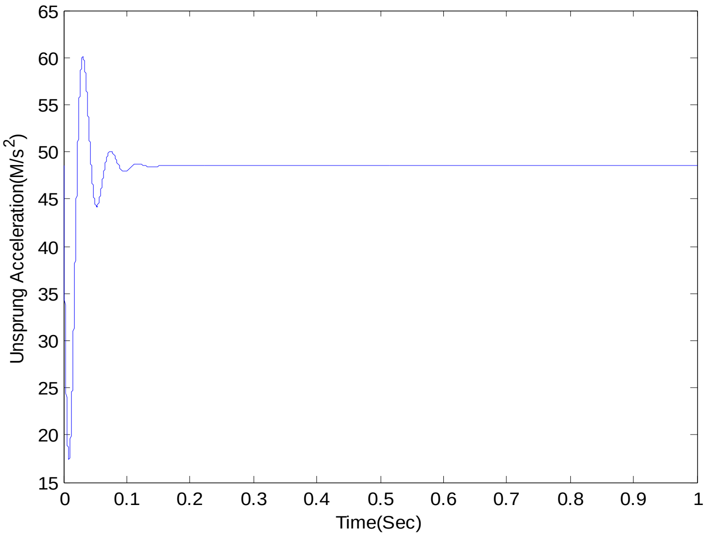

Fig.3.5: Acceleration response of Chassis

IV. Conclusions

In this paper, McPherson suspension system has been modeled after studying dynamic equations to study vibration characteristics of sprung mass of the automobile system with the inclusion of various design parameters such as stiffness, damping, masses, moment of inertia, etc. The commercial simulation software Simulink is used to implement dynamic equations to attain the acceleration and the displacement of the chassis of the automobile during the period in which the vehicle passes through various road conditions.

Due to the complexity involved in the mathematical expressions and executing them into the Simulink software, the model has been simplified with a two-dimensional approach. The Ansys software is used to implement a simplified two dimensional practical model of McPherson suspension.

The results obtained from Ansys model are compared with the mathematical model implemented on Simulink. It is observed that the displacement and acceleration of the chassis of the automobile obtained in Ansys are nearer to the values of mathematical model. With these developed models, the influence of suspension system parameters can be studied on the performance of passenger comfort.

V. Acknowledgements

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