INFLUENCE OF TIRE STIFFNESS AND SPRUNG MASS ON VEHICLE RIDE PERFORMANCE

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Report
Projek Sarjana Muda I

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DECLARATION

"I hereby declare that this report is the result of my own work except for quotes as cited in the references."

Signature : _____

Author's Name : Muhammad Safwan bin Mohammad Nizar

Date : _____

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Automotive) with Honors.

Signature : _____

Supervisor's Name : Mr. Adzni bin Md. Saad

Date : _____

ABSTRACT

Vehicle ride performance should be monitored for every vehicle in order to maximize ride comfort and handling. In this research, the tires were assessed in terms of inflation pressure, rolling resistances and also road surfaces in order to determine the best condition in terms of ride performance. Values of inflation pressure were manipulated in order to obtain different rolling resistance to observe the differences in maximum tractive effort of the vehicle. The data were then compared and determined in which state of tire stiffness is best for ride performance. Other than the testing on tire stiffness, in order to determine the optimal vehicle ride comfort is best to assess the sprung mass' reaction to different road inputs and manipulated variables. Simulations were done in order to observe multiple responses of the sprung mass when its value was increased. The vertical acceleration and displacement of the sprung mass was needed to be analyzed in order to determine is ride quality viable with higher sprung mass. Then, the suspension system is improved in order to compensate the higher value of sprung mass in order to see if it were to be modified, which part of the suspension should be improved. The suspension system used in this research is the passive suspension system as the data obtained was from a 2008 Proton Waja CPS Variant. Every simulation was done using the Matlab Simulink and the passive suspension system was designed according to quarter car suspension model.

ABSTRAK

Prestasi perjalanan kenderaan seharusnya diteliti untuk setiap kenderaan supaya keselesaan dan kawalan semasa perjalanan dapat dicapai pada tahap maksima. Di dalam kajian ini, tayar kenderaan telah dijadikan sebagai bahan uji kaji dan beberapa pemboleh ubah seperti tahap tekanan angin tayar, rintangan pergolekan dan juga jenis permukaan jalan raya untuk menentukan keadaan terbaik bagi tayar tersebut bagi prestasi perjalanan kenderaan. Tahap tekanan angin tayar juga akan divariasikan untuk mendapatkan rintangan pergolekan yg berbeza untuk diteliti dan dianalisa daya maksimum traktif mereka yg berbeza. Dengan perbandingan daya maksimum traktif yang berbeza itu barulah dapat ditentukan pada keadaan mana yang terbaik bagi tayar untuk mencapai prestasi perjalanan kenderaan yang terbaik. Selain daripada kajian terhadap tekanan angin tayar, untuk menentukan keselesaan yang optimal semasa perjalanan, respon pada badan kenderaan terhadap input jalan raya yg berbeza-beza haruslah dikaji. Tindak balas pecutan dan anjakan menegak badan kenderaan akan dikaji berdasarkan simulasi yang dijalankan apabila jisim badan kenderaan dipertingkatkan. Ke hadapan lagi, sistem suspensi itu kemudiannya akan diubah suai dengan mengubah nilai pada kekerasan pegas dan juga pekali redaman kereta untuk melihat perubahan terhadap respon badan kenderaan dari segi pecutan dan anjakan. Sistem suspensi telah dimodel berdasarkan system suspensi pasif berikutan Proton Waja CPS tahun 2008 telah diletakkan sebagai bahan uji kaji. Setiap simulasi telah dijalankan menggunakan Matlab Simulink dan sistem suspensi telah direka bentuk berdasarkan model suspensi suku model kereta.

DEDICATION

To my late father, Mohammad Nizar bin Ahmad

And

Loving mother, Norrihan binti Adnan

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LIST OF ABBREVIATIONS

Equation of Motion	EoM
Free Body Diagram	FBD
Front Wheel Drive	FWD
Crank Position Sensor	CPS
Mitsubishi Innovative Valve Timing Electronic Valve	MIVEC
Sprung/Unsprung Mass	M_s / M_{us}
Spring Stiffness Suspension/Wheels	K_s / K_w
Damping coefficient Suspension/Wheels	C_s / C_w
Sprung/Unsprung Acceleration	$\ddot{Z}_s$ / $\ddot{Z}_{us}$
Sprung/Unsprung Velocity	$\dot{Z}_s$ / $\dot{Z_{us}}$
Sprung/Unsprung Displacement	Z_s / Z_{us}
Road Displacement	Z_r
Force Transmitted	$F_{transmitted}$

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

1.1.1 Vehicle in general

Vehicle becomes a necessity for the general public in this modern era for transportation purposes. In purchasing a vehicle, a majority of general public are not very familiar with all the technical aspects of a vehicle. The general perception by the general public when they are looking for a vehicle is the price to performance ratio or to put it simply “bang for their buck vehicle”. Due to this factor, engineers today had to look for improvements in their engine (fuel efficiency in spite of performance and etc.), suspensions (cornering ability and etc.) and even the tires (threading, thickness and etc.). People may be aware the effects of engine improvement due to fuel efficiency but not many knows the actual performances of the suspensions even though they are as important as the engine itself. The suspension functions as to maximize the friction between tires and the road in order to provide steering ability alongside better handling and to ensure the vehicle ride is comfortable [5]. And the main focus in this study is to investigate the effects of vehicle ride performance and that heeds the improvements of the vehicle suspensions.

1.1.2 Suspensions (springs)

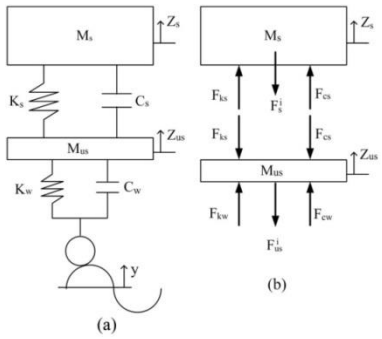

Figure 1.1.1: A representation of the car suspension free body diagram.

Suspensions comprise of numerous parts at which are the springs, shock absorber, anti- sway bars, control arms and etc. (Refer Figure 1.1 for the positions of every parts of the suspension). The springs act as an energy storage device where they are designed to absorb the shock caused by the road surface during compression [7]. The energy is stored in the state of potential energy, when able, the energy is then converted in terms of kinetic energy as the spring expands in order to push the wheel down for maximum road contact [7]. Cars, when it is on the ground, the sprung weight actually compresses the springs, causing any drop in the road surface will result in the spring to press the wheel down for road contact [7]. Other than that, as the spring compresses, it is actually keeping the sprung up off the wheels [6]. Figure 1.1.1 represents for a more clear representation of the motion of spring in the suspension of a car where the spring is represented by the coefficient, *k*, in the diagram.

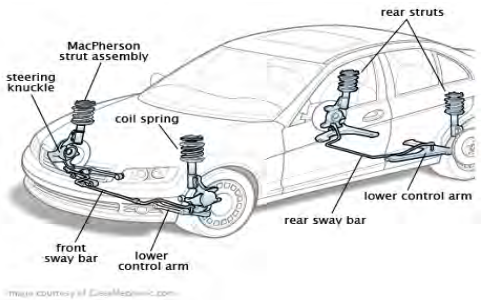

Figure 1.1.2: Figure shows the positions of the suspension of a common vehicle.

1.1.3 Dampers (Shock Absorbers)

While springs are energy storage devices, dampers (shock absorbers) are energy dissipaters. They eliminate the energy stored by the spring during compression by converting it to thermal energy [7]. If there are no dampers, when the vehicle hits a bump, the vehicle would keep on bouncing up and down as the potential energy from the spring was turned into the kinetic energy and the amount of energy is huge for the vehicle to sustain [7]. The motion would keep on going until the energy from the impact of the bump is dissipated entirely [7]. Due to safety, comfort and usability of the vehicle, engineers have designed and put the dampers as a mean to solve that particular problem. The energy dissipation is achieved when the medium within the dampers were forced to pass through small holes of its piston when the springs are in motion. Modern shock absorbers are mostly velocity-sensitive, where they put up more resistance for big bumps and smoother when dealing with light bumps. Refer Figure 1.2 for a more clear representation of the motion of dampers in the suspension of a car where the damper is represented by the coefficient, *c*, in the diagram.

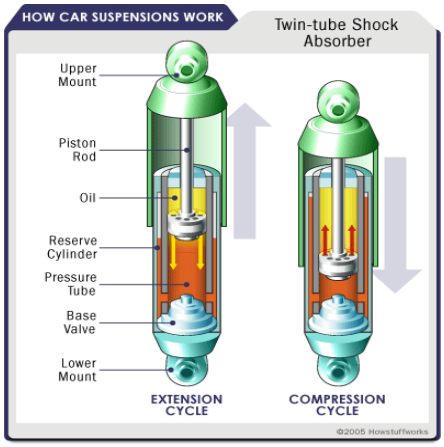

Figure 1.1.3: Figure showing a cross section of a twin-tube shock absorber design.

Sprung mass are the loads sitting at the top of the springs [1] and in the case of automobiles as such of cars, the whole components located above the suspension are the sprung mass. The spring in suspensions is what sprung the loads (the chassis, engine, body and etc.) and cushions it along with the occupants and baggage inside the vehicle [2]. If there are no springs in the suspension, the journey would not be comfortable as the chassis would be banging on the tyres during corners and might even fall apart in a short period of time due to all the shaking and banging [2]. This shows that suspensions plays an important role in making sure vehicle ride performance is at a high.

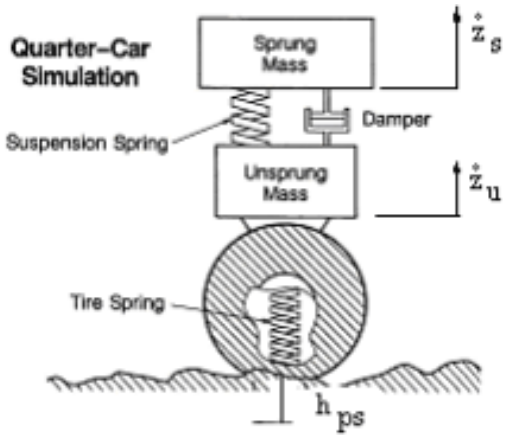

Figure 1.1.4: Figure shows the modelling for the quarter car model for analysis.

The stiffness of the springs is the manipulated variable in determining to what extent the sprung mass reacts to the motion of a vehicle [1]. Suspensions with loose springs are usually found in common vehicles in order to ensure comfort on the road as they absorb shock from the bumps on the road or any road irregularities [1]. Even then, it comes with a few consequences where soft suspensions would result in a dive and squat during braking or acceleration with rollover when cornering [1].

Figure 1.1.5 and 1.1.6: Figure shows a representation for when a car dives during braking and squats when accelerating.

In order to decrease the probabilities of any dives or squats for your vehicle, it could be controlled also by the tire stiffness aside from the spring stiffness. The vertical deflection of a tyre is approximately proportional to the applied vertical force as stated in the Newton's third law where for every action, there is an equal and opposite reaction. Tire stiffness is however majorly (90%) affected by its inflation pressure and obviously there are high stiffness tyres and low stiffness tyres [3]. By referring to the representation during the heaving and roll (Figure 1.1.4 and 1.1.5) where shows the detailed abilities of a high stiffness tire compared to the low stiffness tyre.

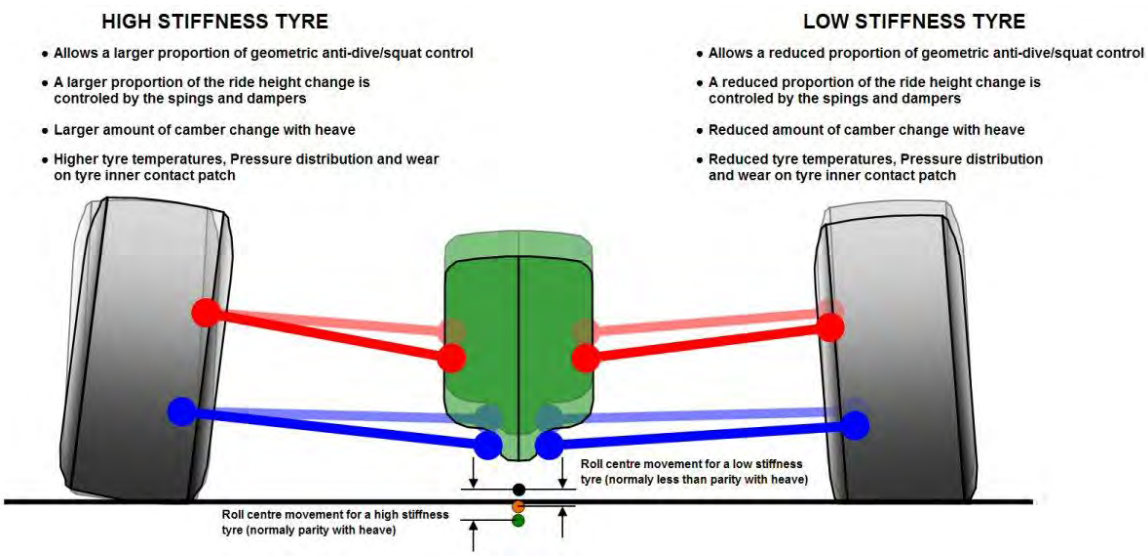

Figure 1.1.7 [3]: A representation and dynamic effects of high and low vertical stiffness tyres on the car with heave.

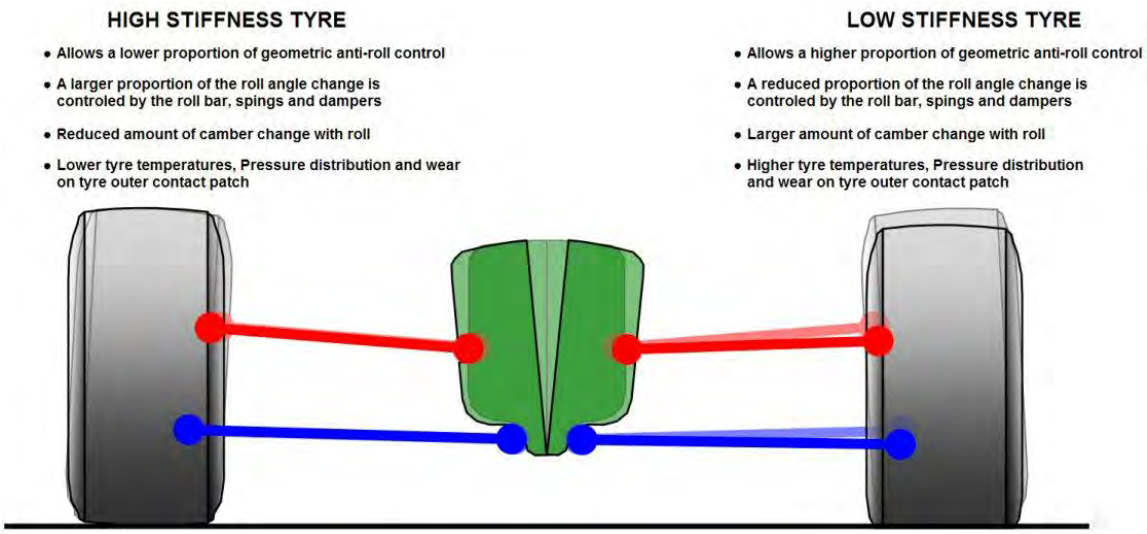

Figure 1.1.8: A representation and dynamic effects of high and low vertical stiffness tyres on the car with heave [3].

1.2 PROBLEM STATEMENT

Roads all over the world consist of road irregularities, such as road bumps, uneven road surface, rubbish thrown and etc. Road irregularities affect a lot of things to a vehicle if they ever happen to be in contact with each other. For example, going over a road bump too fast might damage your suspension and chassis (if the body height is lowered from stock height setting) and this might cause serious damage to the bank account of the driver. Due to that, a research was planned in order to further enhance the performance of the existing suspensions and tire stiffness in order to achieve better vehicle ride comfort for common vehicles.

Figure 1.2.1: An example of road irregularity.

1.3 OBJECTIVE

The objectives of this project are as follows:

- To develop mathematical simulation model of quarter car model of vehicle suspension system.
- To investigate the effects of tire stiffness and sprung mass on vehicle ride performance.

1.4 SCOPE OF PROJECT

This study is only limited to investigate vehicle suspension performance based on mathematical simulation without any experimental work involved. Software that is going to be used is the MATLAB Simulink. Major parameters that influence the performance of suspension system will be discussed in detail.

1.5 GENERAL METHODOLOGY

The actions that need to be carried out to achieve the objectives of this project are listed below.

1. Literature Review.

   Journals, articles, books or even videos will be studied as a research material for the project.

2. Observation, Surveys and Data Collection.

   Human behaviour on the road will be observed and recorded as data. The parameters to be set would be the speed of the vehicle they drove and in what condition were they driving on and etc. Surveys in the form of a Google form will be sent out in order to obtain the actual data or be revised in order to limit the boundaries of assumptions made for the project.

3. Simulation.

   Simulation will be done in the MATLAB Simulink based on the data input from the surveys and the researches from the literature review. Modelling will be done based on formulas and results will be analysed.

4. Analysis, proposed solution and recommendation for improvements.

   Analysis will be presented on how the suspension performance affects vehicle performance and how to further improve this technology. All solutions will be proposed based on the analysis of the project.

5. Report Writing

   A report will be written and submitted at the end of this project.