

# Influence of tire stiffness and sprung mass on ride quality

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**ABSTRACT** – Automobile ride quality is a vehicle characteristic of great importance. It is a factor that consumer is very sensitive to, and which can have a profound influence on passenger comfort. The purpose of this study is to investigate the effects of tire stiffness and sprung mass on ride quality. Numerical simulation is used by representing ideal physical of vehicle quarter car model into Bond Graph. By lowering tire stiffness, it reduces the worst frequency response due to external force but the natural frequency of the system remains the same. However, by increasing the sprung mass, it reduces the natural frequency of the system but the worst frequency due to external forces is comparably same.

## 1. INTRODUCTION

With the purpose of producing customer oriented products, comfort is becoming one of the most important aspect in designing a vehicle. Comfort is perhaps the most obvious attribute to ride quality.

A harsh riding vehicle subjects the passengers to significant acceleration levels. In some cases, for example in trucks and off-road construction equipment, these acceleration levels can cause chronic medical conditions. An overly soft riding vehicle can cause passengers to develop motion sickness.

Safety is an issue from the standpoint of driver fatigue, which may be accelerated in cars with poor ride quality characteristics. However, safety can also be compromised by poor stability and maneuverability characteristics, which can result from a car designed solely to improve ride quality. This can be seen in cars designed as luxury sedans, which handle much worse than sport cars in which suspensions have been designed for handling at the expense of ride quality. Additionally, a harsh riding vehicle may also affect reliability. Car components as well as the driver are subjected to higher forces in a car with poor ride quality. This can limit the life expectancy of the components.

The objectives of this study is to investigate the effects of tire stiffness and sprung mass in ride quality. The changes of these two properties have strong relation to our everyday driving. For the purpose of this study, tire is assumed to be deflated and the stiffness reduces by 35%. For the effect of sprung mass, the car is assumed to have 5 passenger with average mass of 70kg. It increases total sprung mass of the vehicle by 350kg.

## 2. RESEARCH METHODOLOGY

This study was conducted by using 20sim software. Firstly, a quarter car model was used and represented as Bond Graph as shown in Figure 1. Model parameters used for this simulation were shown in Table 1.

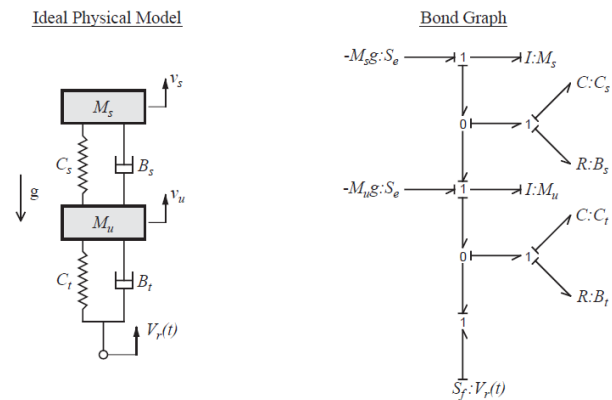


Figure 1 Quarter car model.

Table 1 Model parameters.

Parameters	Values
Sprung Mass, $M_s$ (kg)	1068
Suspension Stiffness, $K_s$ (N/m)	74968
Suspension Damping, $B_s$ (Ns/m)	2800
Unsprung Mass, $M_u$ (kg)	146.4
Tire Stiffness, $K_t$ (N/m)	775660
Tire Damping, $B_t$ (Ns/m)	800

Model input to the system was determined by roughness of the road. Idealized road profile was used and it represented by sinusoidal bumps of wavelength,  $L$  and amplitude,  $R$  (road roughness) as shown in Figure 2. The road profile can be described by Equation (1).

$$y_r(x) = R \sin\left(\frac{2\pi}{L}x\right) \quad (1)$$

For the purpose of this study, constant forward velocity used was 25m/s with road roughness,  $R$  of 0.05m. Wavelength,  $L$  used were 0.5m, 1m, 2m, 2.5m, 6m, 10m, 12m, 15m, 20m, 23m, 30m and 50m.

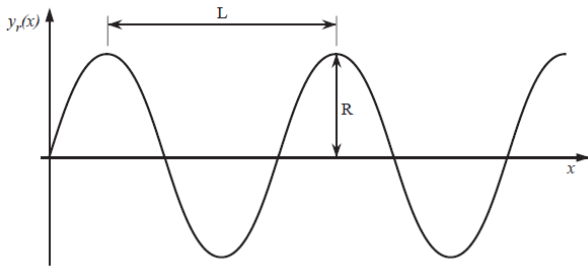


Figure 2 Rough road model.

### 3. RESULTS AND DISCUSSION

In this section, results of the test will be discussed in details. Initial response of the system with original tire stiffness and without any changes of sprung mass obtained from Bode plot showed that the system had two worst bump frequencies. Natural frequency of the system was 8.035 rad/s with magnitude of 29.825 dB. Worst frequency due to input road roughness was 73.621 rad/s with magnitude of 18.054 dB.

For the effect of tire stiffness, it was assumed that the tire was deflated and the stiffness reduced by 35%. Response of the system by having lower tire stiffness was shown on Figure 3 below. It has 2 worst bump frequencies with corresponding amplitudes. Frequency with highest corresponding amplitude was the natural frequency of the system. Based on the plot, the natural frequencies of the system showed minor changes. Natural frequency was 7.852 rad/s with magnitude of 30.242 dB. But, by having lower tire stiffness, it reduced the worst frequency response of the system due to the sinusoidal road profile input. Worst frequency response recorded was 59.566 rad/s with corresponding magnitude of 16.296 dB.

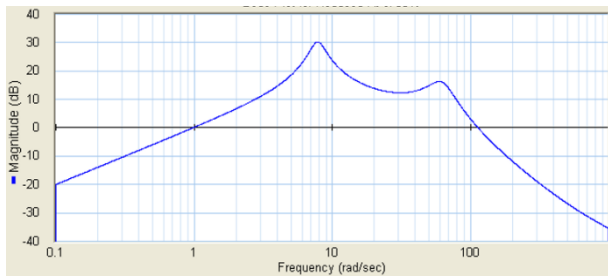


Figure 3 Bode plot of the system with 35% reduction of tire stiffness.

For the effect of sprung mass, it was modeled with the assumption that the vehicle had 5 passengers with average mass of 70kg. It increased total sprung mass by 350kg. The frequency response of the system was shown on Figure 4 below. The system had two worst frequencies with corresponding magnitudes. Frequency with highest magnitude was the natural frequency of the system and the other frequency was the worst frequency response

due to external force that acting on the system. Based on the plot, by increasing the sprung mass it reduced the natural frequency of the system. The new natural frequency was 6.966 rad/s with magnitude of 29.705 dB. But, the worst frequency of the system due to the external forces was comparably same with initial condition. By increasing the value of sprung mass also increased tire deformation. Tire deformation response was shown in Figure 5 below. The steady state value of the deformation was 0.02m.

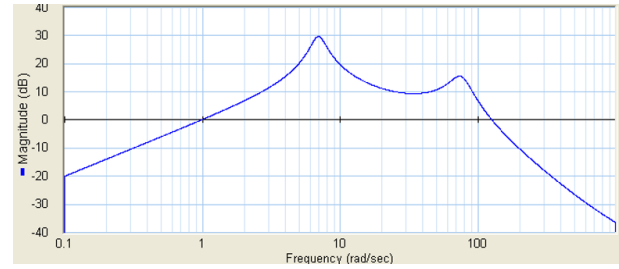


Figure 4 Bode plot of the system with 350 kg additional sprung mass.

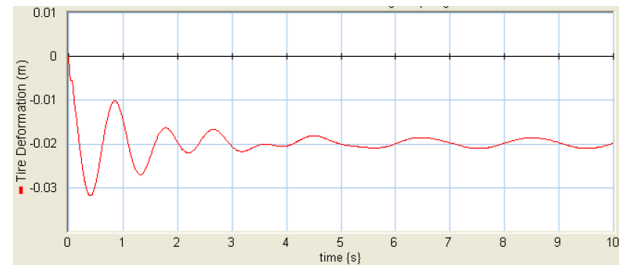


Figure 5 Tire deformation of additional 350 kg of sprung mass.

### 4. SUMMARY

This study was carried out to determine the effects of tire stiffness and sprung mass on ride quality. Numerical simulation by utilizing 20sim software was used as tool for this investigation. Ideal physical quarter car model was represented by using Bond Graph. Results showed that by lowering tire stiffness, it reduced the worst frequency response but the natural frequency of the system remained the same. However, by increasing the sprung mass, it reduced the natural frequency of the system but the worst frequency due to external forces was comparably same.

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