# Simulation of Vehicle Ride Models Using ADAMS

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***Abstract: The comfort level and ride stability of a vehicle are two of the most important factors in a vehicle's subjective evaluation. In the design of a conventional suspension system there is a trade off between the two quantities of ride comfort and vehicle stability. There are two basic types of elements in conventional suspension systems. These elements are springs and dampers. The role of the spring in a vehicle's suspension system is to support the static weight of the vehicle. The role of the damper is to dissipate vibrational energy and control the input from the road that is transmitted to the vehicle. This paper presents the simulation of vehicle ride model. This model may be used for vehicle suspension testing to carry out the ride analysis at different vehicle speeds. The quarter and the full vehicle model are created, using ADAMS (Automatic Dynamic Analysis of Mechanical Systems). The two models include all sources of compliance; stiffness and damping. The road excitation is causing sudden vertical movements between the bump and the rebound. Therefore, the suspension moves, the position and orientation is calculated. The main output from this analysis is the response in terms; displacement, velocity, and acceleration. These parameters are measure of stability and ride comfort at different vehicle speeds. This paper introduces the simulation of vehicle ride models via quarter (2-DOF) and full vehicle model (6-DOF)***

***Keywords: Quarter Vehicle model, full vehicle model, ADAMS, Ride comfort***

## I. Introduction

A considerable research are conducted by many researchers [1-6] to define ride comfort limits. They include shake test, ride simulator experiment. These method attempt to correlate the response of test subject in terms; discomfort zone and comfort zone with vibrational parameters such as displacement, velocity, and acceleration. For good ride, the natural frequency of the body is around 1 Hz. The evaluation of ride quality of an automobile over a given roadway at constant speed can be investigated. The recommended root mean square, for ride quality is 0 – 0.04 g for smooth rides, 0.04 g – 0.06 g for medium rides and above 0.06 g for rough rides. Often for good ride comfort the suspension system should provide a relatively low vertical stiffness which conflicts with the requirements for a good handling analysis. These conflicting requirements have led to the gradual introduction of independent suspensions, adjustable systems and active elements. Accordingly, analysis of suspension performance in the design stage, using computer simulation is helpful in optimization of the system. Therefore, this paper introduces a quarter model with 2-DOF and full vehicle model with 6-DOF for the purpose of ride comfort study.

## 2. Vehicle Ride Model

### *2.1 Quarter Vehicle*

Consider the simple 2-DOF model shown in Figure 1, the two equations of motions are given as in equation (1) and (2):

$$m_s\,\ddot{z}_1 = k_s(z_2 - z_1) + c_s(\dot{z}_2 - \dot{z}_1) \quad (1)$$

$$m_{us}\,\ddot{z}_2 = k_t(z_0 - z_2) + c_t(\dot{z}_0 - \dot{z}_2) - k_s(z_2 - z_1) - c_s(\dot{z}_2 - \dot{z}_1) \quad (2)$$

Assuming harmonic motion of base and the masses, then

$$z_i(t) = Z_i e^{j\omega t} \qquad i = 0,1,2 \qquad j = \sqrt{-1}$$

$$\dot{z}_i(t) = Z_i\; j\omega\, e^{j\omega t} \qquad i = 0,1,2$$

$$\ddot{Z}_i(t) = -Z_i\,\omega^2\, e^{j\omega t} \qquad i = 0,1,2$$

The frequency response functions for the two degrees of freedom, for sprung and unsprung masses are investigated in equation (3) and (4):

$$\frac{z_1}{z_0} = \frac{(k_s + c_s j\omega)(k_t + j\omega c_t)}{\left(-m_{us}\omega^2 + k_t + k_s + j\omega(c_t + c_s)\right)\left(-m_s\omega^2 + k_s + c_s j\omega\right) - \left(k_s + c_s j\omega\right)^2} \quad (3)$$

$$\frac{z_2}{z_0} = \frac{(-m_s\omega^2 + k_s + c_s j\omega)(k_t + j\omega c_t)}{\left(-m_{us}\omega^2 + k_t + k_s + j\omega(c_t + c_s)\right)\left(-m_s\omega^2 + k_s + c_s j\omega\right) - \left(k_s + c_s j\omega\right)^2} \quad (4)$$

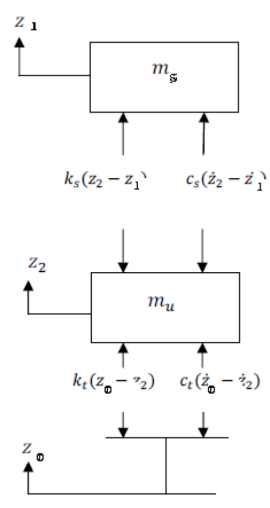



Fig. 1: Quarter 2-DOF model

### *2.2 Simulation of Quarter Vehicle Model*

The quarter vehicle model is simulated, using ADAMS (as shown in Figure. 2. The sprung and unsprung is attached using two translational joints. The suspension stiffness (spring and damper) are attached between the sprung and unsprung mass. The road excitation is simulated using imposed motion using translational joint as a function with time. The input data for model is given in Table: 1. Because of road excitation, the sprung and unsprung mass is exposed to sudden vertical movements between the bump and the rebound.

TABLE 1: Input Data for quarter car model

| No. | Parameters | Value |
|---|---|---|
| 1 | Sprung mass | 250 kg |
| 2 | Unsprung mass | 25 kg |
| 3 | Suspension stiffness | 20 N/mm |
| 4 | Shock absorber damping coefficient | 1 N. sec/mm |
| 5 | Tire stiffness | 100 N/mm |
| 6 | Vehicle speed | 21.6 km/h |
| 7 | Excitation: Sinusoidal road input:<br>1) Wave length<br>2) Amplitude<br>3) Vehicle speed<br>$f=\frac{V}{\lambda}=\frac{27}{3.6\times3}=2.5\ Hz$ | <br>3.0 m<br>20 mm<br>27 km/h |

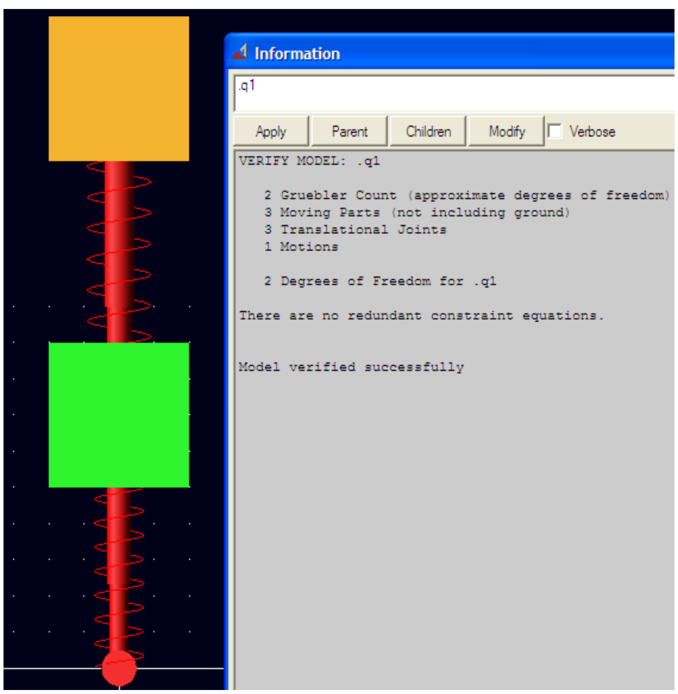
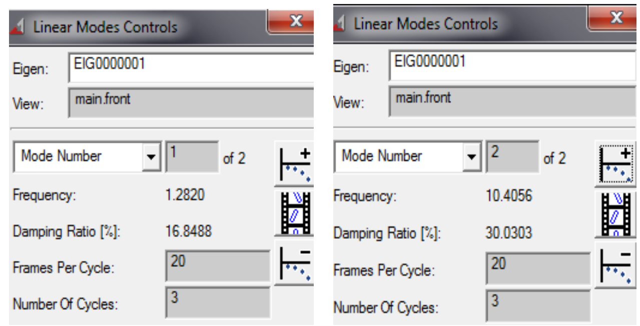



Fig. 2 Quarter Vehicle model

The model is simulated to 5 sec. and 2000 steps. Sample of results are highlighted. The two natural frequency of sprung and unspring mass are 1.282 Hz and 10.41 Hz respectively as shown in Figure 3. Consider the vehicle moves with speed 27 km/h on sinusoidal road input with wave length 3 m then the road frequency is 2,5 Hz. The variations of vertical displacement and acceleration of sprung mass and unsprung mass with time is shown in Figure 4. It is clear that the sprung mass displacement is less than the unsprung mass. Therefore, good isolation of suspension system is obtained




(a) Sprung mass (b)unsprung mass

Fig. 3 The natural frequencies of sprung and unsprung masses

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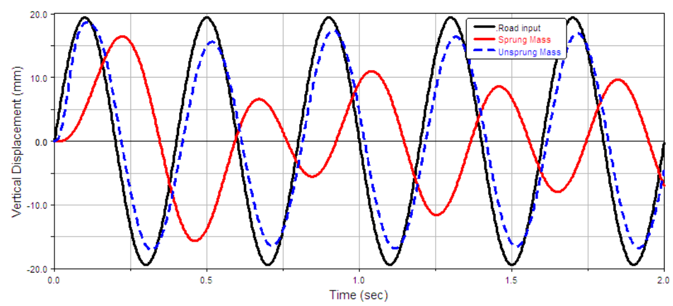
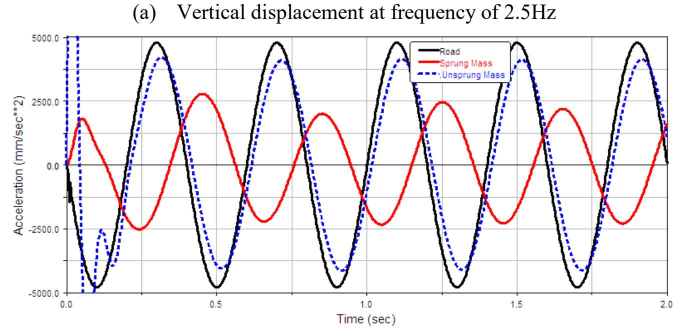



(a) Vertical displacement at frequency of 2.5Hz




(b) Vertical acceleration at frequency of 2.5Hz

Fig. 4 Variations of vertical displacement and acceleration with time

For vehicle speed increased to be double 54 km/h then the road frequency is 5 Hz. The variations of vertical displacement and vertical acceleration of sprung mass and unsprung mass with time is shown in Figure 5 for vehicle moves with speed 54 km/h on sinusoidal road input with frequency 5 Hz. It is clear that the sprung mass vertical displacement and the acceleration less than the unsprung mass. Therefore, good isolation of suspension system is obtained.

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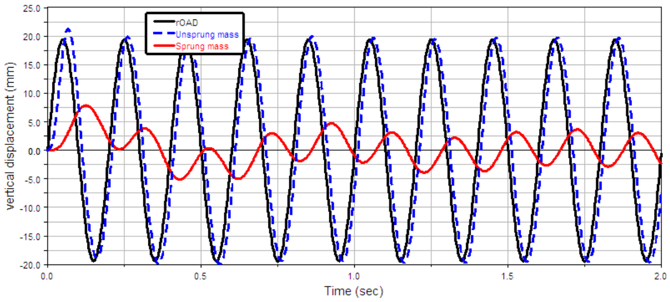
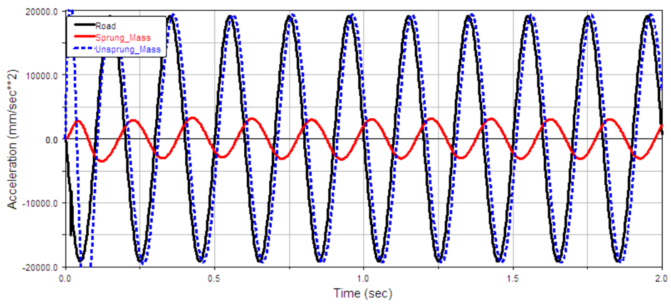



(a) Vertical displacement at frequency of 5Hz




(a) Vertical acceleration at frequency of 5Hz

Fig. 5 The variation of vertical displacement and acceleration with time

## 3. FULL VEHICLE MODEL

Unlike quarter, vehicle model where only one wheel is analyzed full vehicle model considers 4- wheel, 2- front and 2- rear wheel. The main advantages of this type of models are

1. Body pitch motion is simulated
2. Body bounce motion is simulated.
3. Front and rear suspensions system are modeled differently

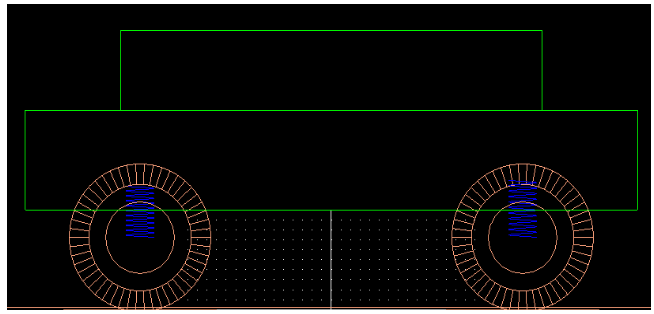
The full vehicle model shown in Figure 5 has 10 parts; 4-wheel, vehicle body and dummy part and 4-jack simulating the road motions under front and rear axle. The parts and constraints in model are:

| | |
|---|---|
| 10 Moving Parts | (60) |
| 1 Revolute Joints | (-5) |
| 9 Translational Joints | (-45) |
| 4 Motions | (-4) |

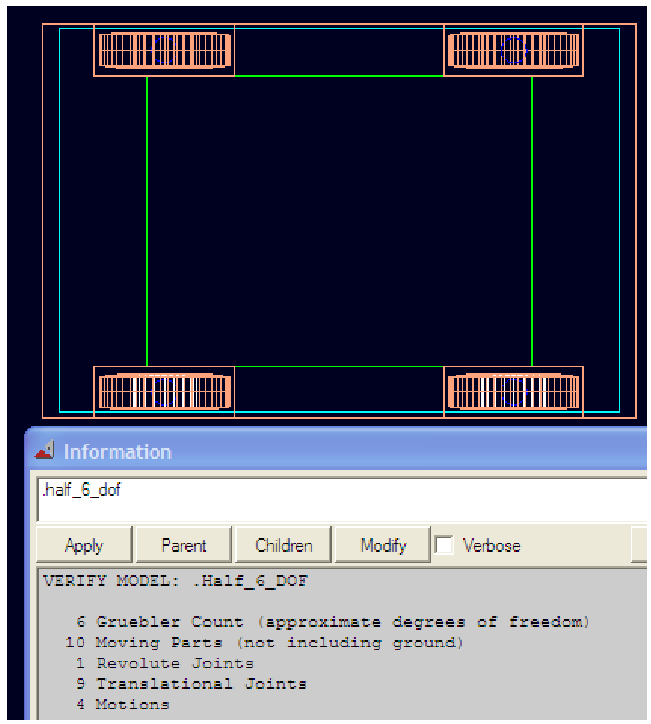
The 6-DOF is:

2- DOF for Pitch and bounce of vehicle body
4- DOF for wheels bounce

The full vehicle model is simulated to 5 sec. and 2000 steps. Sample of results are highlighted. The road input for front axle is simulated using sinusoidal function with amplitude 50 mm with frequency 2 Hz. While the road for rear axle is simulated using cosine road input with amplitude 50 mm with frequency 2 Hz. The shape of road input is shown in Figure 6. For front axle use the function: 50.0 * SIN (2*3.14*TIME). For rear axle use the function: 50.0 * COS (2*3.14*TIME). Therefore, at time= 0, the displacement on rear wheels is 50 mm while at front 0 mm.



(a) Side view of half vehicle model
(b)




(c) plan view of half vehicle model
Fig. 5 Half Vehicle model

The variations of body pitch angle and body bounce (vertical displacement) are shown in Figure 7(a) and 6(b). The variation of tire load for front and rear tire is shown in figure 7(c). It is clear the tire load become 0 when the tire is lifted on the ground.

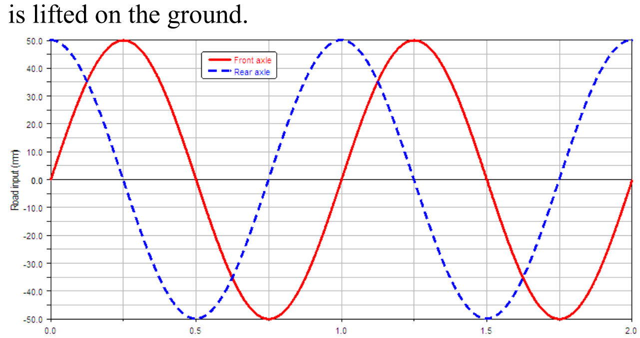
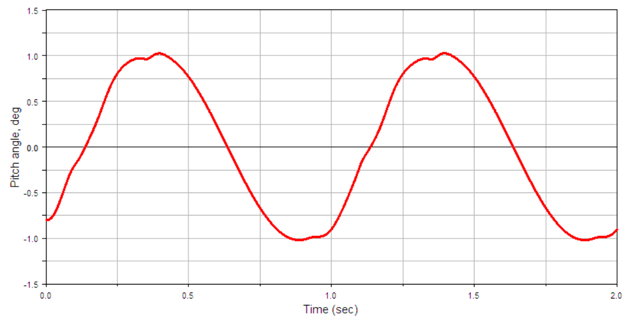
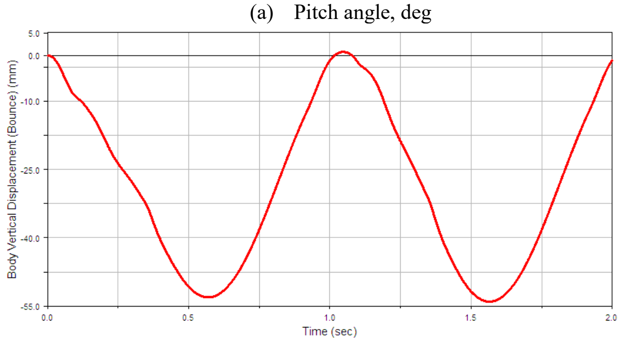


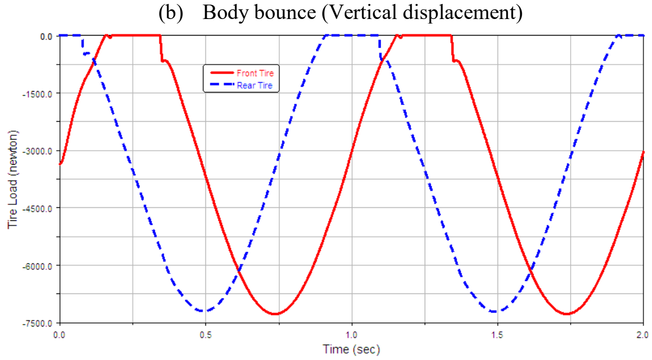

Fig. 6 road input




(a) Pitch angle, deg




(b) Body bounce (Vertical displacement)




(c) Tire vertical load

Fig. 7 The performance of full Vehicle model

## 4. CONCLUSIONS

This paper introduced two different model using ADAMS to simulate vehicle ride characteristics. These are 2- DOF and 6-DOF model. The quarter vehicle model where only one wheel is analyzed but full vehicle model considers 4 wheels; two - front and two- rear wheel. The main advantages of this type of models are the user may be able to simulate the body pitch and bounce motions. Also the front and rear suspensions system are modeled differently

Based on simulation results, the suspension characteristics have a great effect on the ride performance. Therefore, the suspension stiffness and shock absorber characteristics must be calculated according to vehicle weight and must satisfy natural frequency of the body around 1 Hz and give minimize body acceleration for good isolations.

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