SIMULATION OF VERTICAL QUARTER CAR MODEL WITH ONE AND TWO DOFs

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Abstract: *this paper deals with the simulation of vertical displacement vehicle car body with one and two DOFs by using and comparing results of two softwares Working Model and MatLab. The aim of this paper was to show that is very easy is to solve the differential equations that describe both models of vehicle system with one and two DOFs. The results simulations performed with both software's are almost the same for calculating displacement and velocity of sprung and unsprung mass and for different road excitations. The results of simulations have been analysed in terms of stability and road holding since sprung mass or vehicle body oscillations have direct impact on the passenger comfort.*

Key words: WORKING MODEL, SPRUNG MASS, UNSPRUNG MASS, DOF.

1. Introduction

The dynamics of vehicle suspensions is usually highly nonlinear.

2. Quarter car model with one DOF

The model of the quarter-car is adopted by considering as the sprung mass the mass of vehicle car body, shown in Fig 1. Car body mass $\boldsymbol{m_k}$ is connected to a spring with a stiffness coefficient $\boldsymbol{c_v}$ and damping coefficient of shock absorber $\boldsymbol{k_v}$. Mass of tire is $\boldsymbol{m_a}$, which is considered as a solid body, while its deflection is $\boldsymbol{z_r}$, displacement of sprung mass or vehicle body is $\boldsymbol{z_k}$.

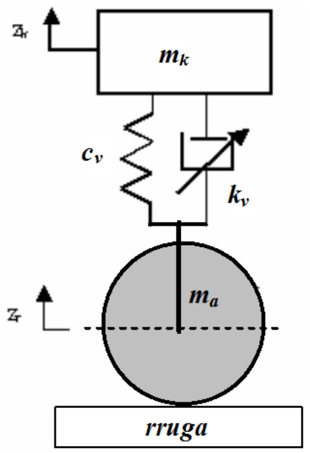


Fig. 1 *Quarter car model with one DOF*

For the simulation in Working Model have been used values shown in table 1, which belong to the VOLVO S400.

Table 1: *Simulation parameters for a quarter car model with one DOF*

Tire mass	m_a = 33 kg
Body mass	m_k = 250 kg
Spring stiffness	c_v = 9000 N/m
Damping coefficient	k_v = 1861 Ns/m

The adopted model with one DOF in Working Model is shown in Fig.2. It should be emphasized that during the design of the model in the Working Model, this task is carried out with constructive data of the model. The method of gaining results by this software is based on solving the differential equations, describe the model oscillations, which are not necessary to describe. After performing the simulation, the results can be exported and stored as a Media File - Film.

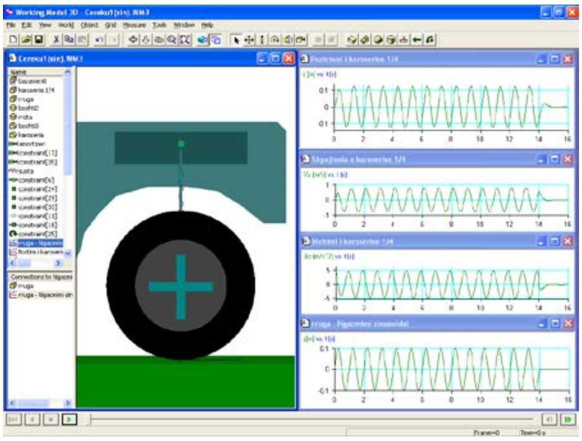


Fig. 2 *Quarter car model simulation with one DOF in Working Model*

The road excitation is taken in sinusoidal form with the maximum amplitude ±0.1m. In Fig. 2 are shown the diagrams for displacement, velocity and acceleration of vehicle body and the road excitation from 0 to 14s.

3. Quarter car model with two DOFs

The model of the quarter-car with two DOFs is adopted by considering as the sprung mass the mass of vehicle car body, shown in Fig 3. Car body mass $\boldsymbol{m_k}$ is connected to a spring with a stiffness coefficient $\boldsymbol{c_v}$ and damping coefficient of shock absorber $\boldsymbol{k_v}$. Mass of tire is $\boldsymbol{m_a}$, is considered as elastic body with a stiffness coefficient $\boldsymbol{c_p}$. For the simulation in Working Model have been used values shown in Table 2, which belong to the VOLVO S400.

Table 2: *Simulation parameters for a quarter car model with two DOFs*

Tire mass	m_a = 33 kg
Body mass	m_k = 250 kg
Spring stiffness	c_v = 9000 N/m
Damping coefficient	k_v = 1861 Ns/m
Tire stiffness	c_p = 177500 N/m

While its deflection is $\boldsymbol{z_r}$, displacement of sprung mass or vehicle body is $\boldsymbol{z_k}$.

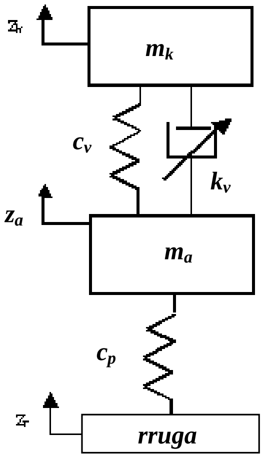


***Fig. 3** Quarter car model with two DOFs*

Results of simulation for the adopted model with two DOFs in Working Model are shown in Fig.4.

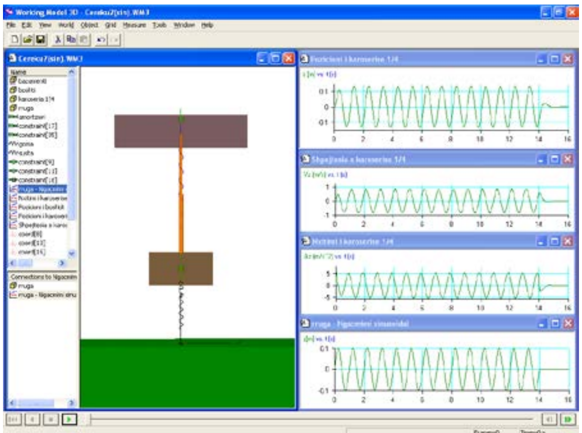


***Fig. 4** Quarter car model simulation with one DOF in Working Model*

The road excitation is taken in sinusoidal form with the maximum amplitude ±0.1m. In Fig. 4 are shown the diagrams for displacement, velocity and acceleration of vehicle body and the road excitation from 0 to 14s.

4. Solving differential equations of the vertical body oscillations with two DOFs in Matlab/Simulink

In the following figures are shown the results of simulation of the vehicle car body with two DOFs

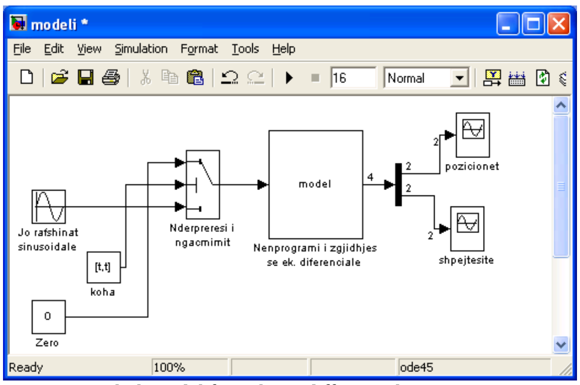
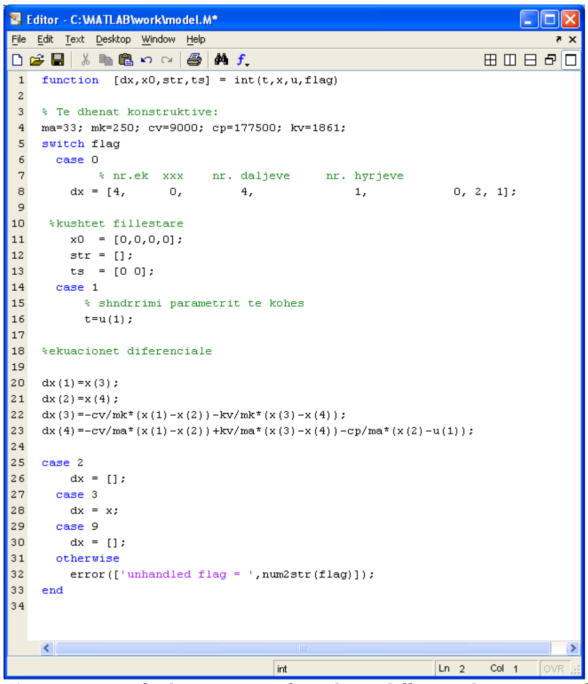


***Fig. 4** Main Simulink model for solving differential equations*



```
function [dx,x0,str,ts] = int(t,x,u,flag)

% Te dhenat konstruktive:
ma=33; mk=250; cv=9000; cp=177500; kv=1861;
switch flag
  case 0
        % nr.ek  xxx   nr. daljeve    nr. hyrjeve
    dx = [4,     0,      4,             1,          0, 2, 1];

 %kushtet fillestare
    x0  = [0,0,0,0];
    str = [];
    ts  = [0 0];
  case 1
      % shndrrimi parametrit te kohes
      t=u(1);

%ekuacionet diferenciale

dx(1)=x(3);
dx(2)=x(4);
dx(3)=-cv/mk*(x(1)-x(2))-kv/mk*(x(3)-x(4));
dx(4)=-cv/ma*(x(1)-x(2))+kv/ma*(x(3)-x(4))-cp/ma*(x(2)-u(1));

case 2
    dx = [];
  case 3
    dx = x;
  case 9
    dx = [];
  otherwise
    error(['unhandled flag = ',num2str(flag)]);
end
```

***Fig. 5.** Listing of subprogramme for solving differential equations of to DOFs.*

The simulation results in MatLab are shown in figures 6, 7, 8 and 9.

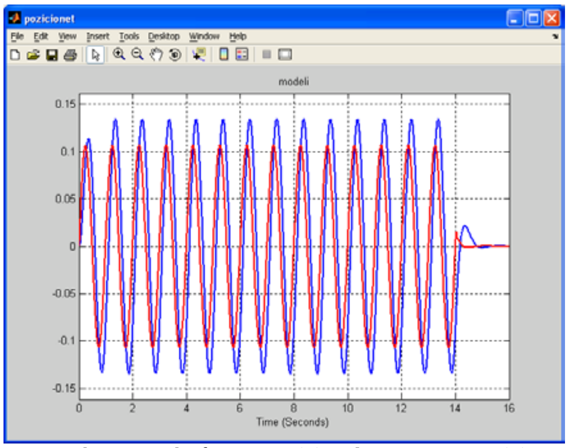


***Fig. 6.** Simulation results for sprung (--) and unsprung mass (--) displacement with sinusoidal road excitation.*

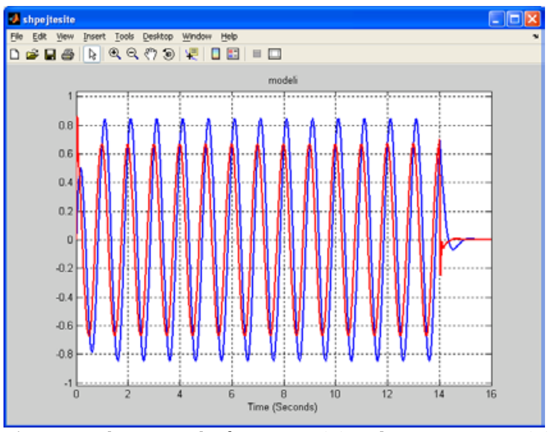


***Fig. 7.** Simulation results for sprung (--) and unsprung mass (--) velocity with sinusoidal road excitation.*

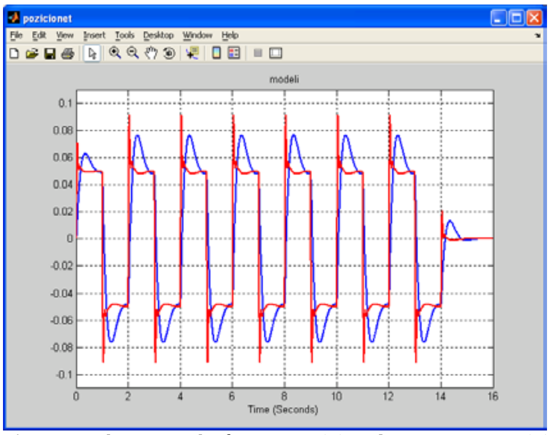


Fig. 8. *Simulation results for sprung (--) and unsprung mass (--) displacement with white noise road excitation.*

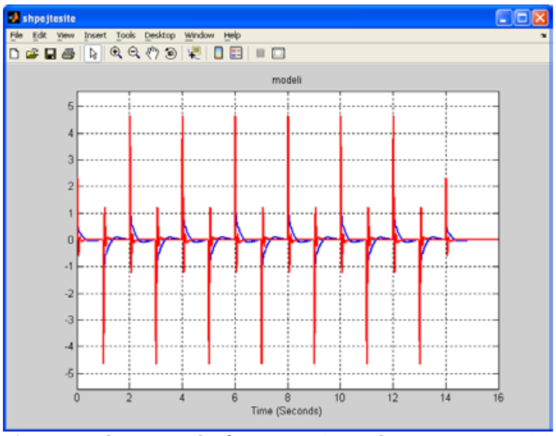


Fig. 9. *Simulation results for sprung (--) and unsprung mass (--) velocity with white noise road excitation.*

4. Conclusions

From the simulation results obtained with Working Model 3D, both quarter car models with one DOF and two DOFs we have observed the following:

-Oscillations of the unsprung mass are very small, so their impact on driving comfort is very small, which might justify the fact that this DOF is not considered, but it should not be forgotten the fact that maintaining a constant wheel contact to the road surface is very important factor for the safety and stability of the vehicle under all driving conditions.

- Oscillations of the sprung mass represent the main oscillations of the vehicle and have direct impact to the comfort of the vehicle, but for the design of the sprung mass, should be a solution that would ensure optimum comfort but also optimal road holding.

- From the characteristic example of the used data of the constructive parameters of the VOLVO S400, we have proved that these extreme types of road excitations are very successful. After the interruption of the road excitation for about 1 second, the stabilization of the vibration of the sprunged mass is achieved, while for the unpruged mass is reached for 0.5 seconds.

For the forced vertical oscillations of the model quarter car with two DOFs, the solution of the second order of differential equations performed in Matlab / Simulink, are almost the same with solutions that have been obtained with working model.

5. References

[1] Likaj,R.(2012): *Simulimi i sistemeve mekanike*,, Prishtina (corresponding author).
[2] M. Gipser (2006): *Multibody Dynamics*, FH Esslingen, Germany,
[3] R.N.Jazar (2008): *Vehicle Dynamics-Theory and Applications*, Manhattan College, USA 2008.
[4] D. Karnoop (2004): *Vehicle Stability, University of California*, Davis, USA.