REGIONAL WORKSHOP

TRANSPORT RESEARCH
AND BUSINESS COOPERATION IN SEE
6 - 7 December 2010, Sofia

THE INFLUENCE OF PHYSICAL CONDITIONS OF SUSPENSION RUBBER SILENT BLOCKS, IN VEHICLE HANDLING AND ROAD-HOLDING

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ABSTRACT

In this paper has been represented a simulation to study the influence of physical conditions of suspension rubber bushing , in vehicle handling and road-holding.
Special attention has been made to determine how shock absorbers' status and silent blocks aging effects on handling and road holding. To do this, has been used a multibody model of a real passenger car and a computer simulation with CarSIM.
The elastic parameters of some rubber bushing, being parts of suspension elements are varied relatively, in order to evaluate the influence of their physical conditions and aging on vehicle handling during a normal braking process.

Keywords: suspension, silent blocks aging, braking process, shock absorber status, tire angles, rubber bushing.

INTRODUCTION

It is clear that handling qualities and road holding capacities of a vehicle, depends from their constructive designs. But as long as the vehicle is new enough, the performance of the vehicle is satisfied. The problems begins when the elastic characteristics of rubber bushings that connect various parts of vehicle suspensions and shock absorbers, are altered physically and time has made them "aged".

Rubber bushings can be also found in almost all vehicle suspension systems. The suspension components are connected to each other, to the subframe, and to the body structure via the rubber bushings. They serve to isolate minor vibration, reduce transmitted road shocks, operate noise free, and should be very durable.

The shock absorbers also, are together with the springs the main force components in the suspension system. The shocks absorbers are designed to slow down the suspension movement and have usually nonlinear characteristics. The physical conditions of the shock absorbers and rubber silent blocks in a suspension, does affect the vehicle handling and driving safety significantly. Since the damping characteristics of the shocks deteriorate gradually over time, the decline in ride control may even pass unnoticed. Furthermore the clearance in the whole suspension is increased due to the worn damper bushings as well as all bushings in vehicle suspension

The modern vehicles also are equipped with some electronic systems and devices permitting the drivers to handle properly, various situations. The interventions of these equipments and systems is not guaranteed if all rubber bushings are not in good conditions.

The famous German company TÜV Rheinland Group in 2002, has made a study in which has estimated that one of every eight personal vehicles in Germany has defective shock absorbers. Their experiments has indicated that usurated shock absorbers can compromise the proper handling of the vehicle and an increase of the braking distance beginning from the speed 80 km/h, by two to three meters.

In Albania we do not have such a data, but if we are considering the albanian road quality and average age of our vehicle fleet, the situation is not expected to be better, but worst.

There are many studies in literature pointing in the influence of active suspensions in decreasing braking or stopping distance. In the actual study attention has been shown in the influence of aging of suspension rubber bushings in braking performance of the vehicle. For this, a vehicle has been modeled and simulated with the aid of a computer program.

VEHICLE MODEL

The study is based on a vehicle model presented in the work of Valasek (2004), which describes a lower middle-class passenger car. The vehicle is designed with front McPherson strut and torsion beam suspension in the rear. In order to simulate an emergency braking manoeuvre, the brake substructure is included in the model as indicated in Figure 1.

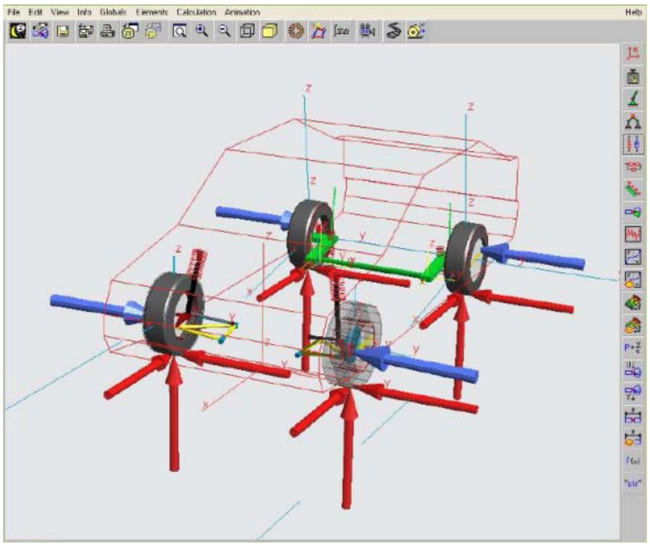

Fig. 1. Graphic representation of a multibody model of a middle-class vehicle.

The contact between the vehicle and the road is modelled with the tyre substructure consisting of four Pacejka similarity tyres. The default data set from the CarSIM database is applied. The front suspension system has been significantly modified, in order to include the elastokinematics, i.e. the rubber bushings in the suspension system. In each of both McPherson suspensions three bushings are added. Two bushings are located on the connection point of the arm to the carbody. The third bushing is modelled between the upper part of the shock absorber and the carbody. The bushings are modelled as component force elements with stiffness in x, y and z direction (so-called KelvinVoigt element). The kinematic chart of the McPherson front wheel suspension with elastokinematics is presented in Fig. 2.

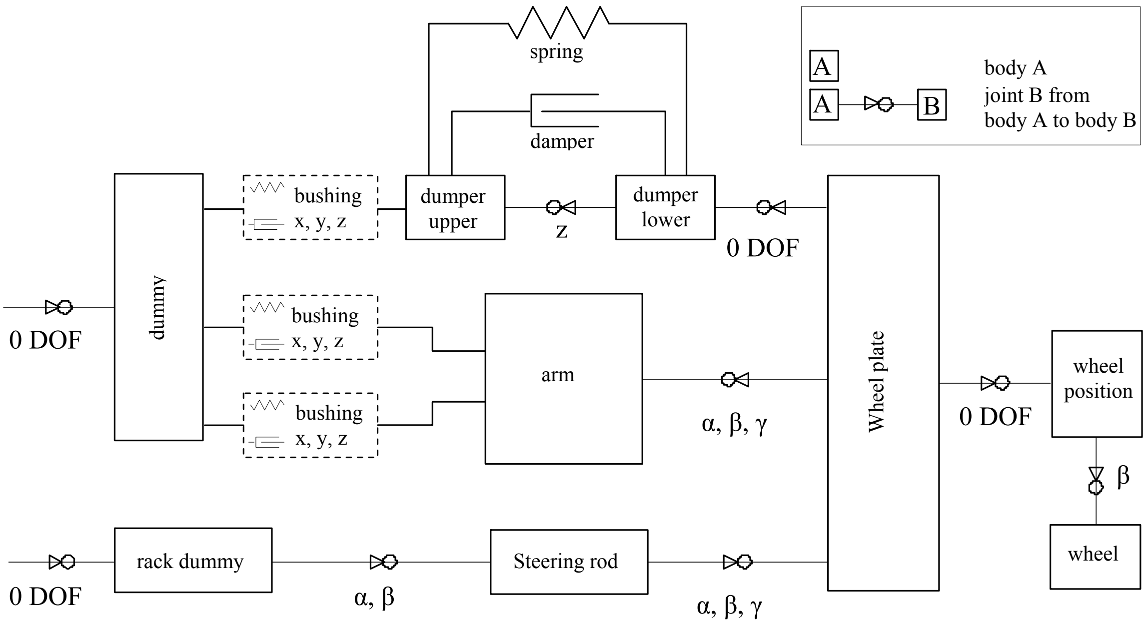

Fig.2. Algorithm of the McPherson front wheel suspension with elastokinematics.

The chart describes the substructure, which is then connected to the vehicle on the left and right hand side. The body dummy is to be connected with zero degrees of freedom to the carbody and the body rackdummy to the steering substructure. However, the steering substructure is not implemented in this model, thus this body is also connected with zero degrees of freedom to the carbody as well. A graphic representation of the McPherson substructure with bushings is presented in Figure 3. The elastic bushings are marked with arrows.

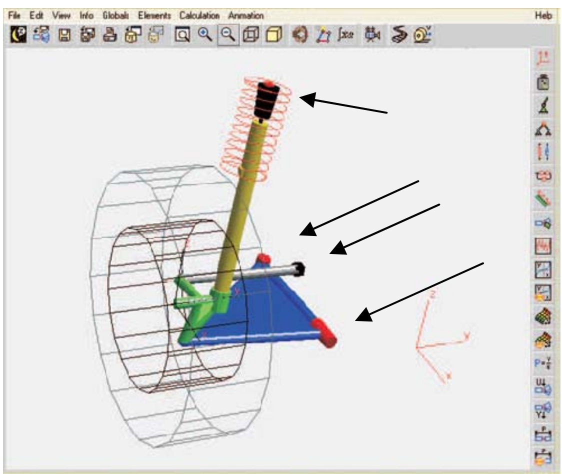

Fig.3. Graphic representation of the mutibody model of the McPherson strut

As a result of this modification the model has no kinematic loops in the McPherson suspension, i.e. the advantage is that the model can be easily described with ordinary differential equation. On the other hand the bushings with a relatively high stiffness and low mass suspension arms introduce high eigenfrequencies up to about 500 Hz.

The parameters of the rubber bushings have been selected according to the literature, particularly Blundell (1998), Roscher et al. (2002) and Tobol´aˇr (2005). Finally the rubber bushings characteristics are estimated as linear static characteristics with relatively low constant damping in parallel. The component stiffness is set to 2.9 10^7 N/m with the exception of vertical stiffness of the shock absorber bushing, which is chosen $1.0 \cdot 10^8$N/m. The component damping ratio is selected to 1.0 10^3 Ns/m. The marginal shocks have less than 50 percent damping ability than new shocks. In order to see the trends the characteristics of the shocks are reduced to 50, 30 for the worn shocks and even shocks without any functionality are simulated. They represent the worst case – the defective shocks.

The worn rubber bushings are represented with a stiffness reduced to about one third of the new and a clearance of 2 millimetres is added.

In order to simulate the stopping distance at the emergency braking the vehicle brakes must be equipped with the anti-locking system. The structure of the model of the antilocking system has four wheel sensors and four modulators (4S4M). Since the first simulation experiments should indicate the trends, the detailed modelling of the anti-lock brakes is not necessary. Thus a simplified generic model can be used, which takes the information on wheel slip directly from the tyre model.

The vehicle is modelled as a multibody system including the anti-lock brakes in the CarSIM simulation package. The model has thirty degrees of freedom. Since the anti-lock brakes are also described as a dynamic system, the model is of order 64.

SIMULATION SCENARIO

In order to study the influence of the deterioration of vehicle components on the vehicle active safety the emergency braking manoeuvre is chosen. The vehicle should stop from the initial velocity 100 km/h and the stopping distance is compared. The vehicle model runs on a straight road the CarSIM database (Fig. 4, Fig. 5, Fig. 6).

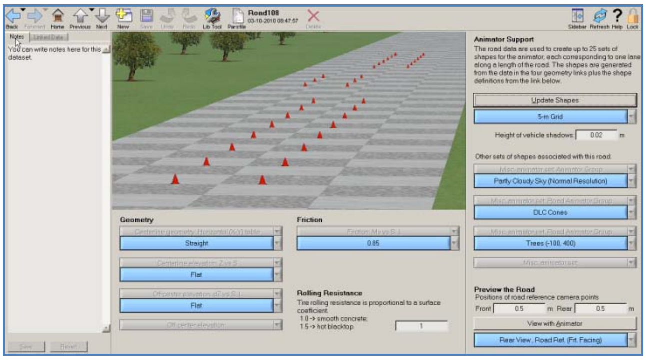

Fig. 4. Modelling ofstraight road with the CarSIM database.

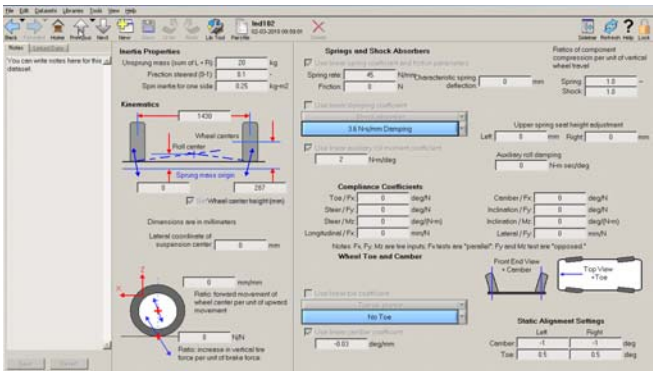

Fig. 5. Tire angles of the vehicle.

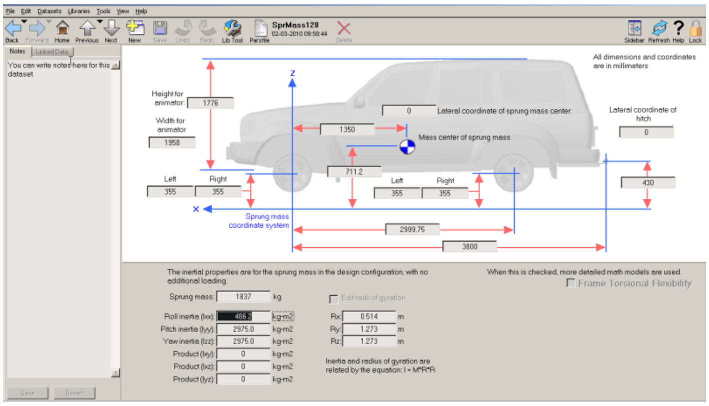

Fig. 6. Geometrical parametres of the vehicle.

The braking manoeuvre begins at the time 1 s with the full braking. The total simulation time is 5 s, however the vehicle stops usually earlier. After stopping of the vehicle the simulation is aborted (Fig. 7).

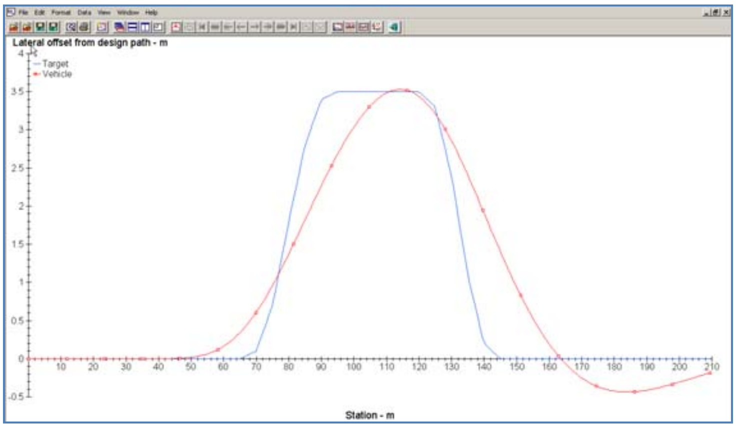

Fig. 7. Lateral offset from design path.

The absolute stopping distance depends on many factors and vehicle parameters, particularly on the friction between the road and the tyre. The friction depends not only on the material and conditions of the road surface, but also on the tyre properties and their conditions. Because of that the simulation results are considered to be relative and should serve to compare the trends and cannot be compared to the other results measuring the stopping distance.

SIMULATON RESULTS

Several simulation experiments have been performed in order to study the influence of the worn or defective shocks. The first series is focused on the conditions of the front axle; the rear axle has the original characteristics. The simulation results are presented in Table 1.
It could be considered as surprising that the worn bushings have no influence on the stopping distance for new or worn shocks. For the defective shocks the stopping distance is even shorter for the worn bushings with the clearance. It happes due to the wheel toe angle.

The worn bushings results in wrong directional stability of the vehicle, the toe angle of each front wheel is negative. As a result of increased toe angle the tyre force has also an lateral force component. The situation is documented in Fig.8.

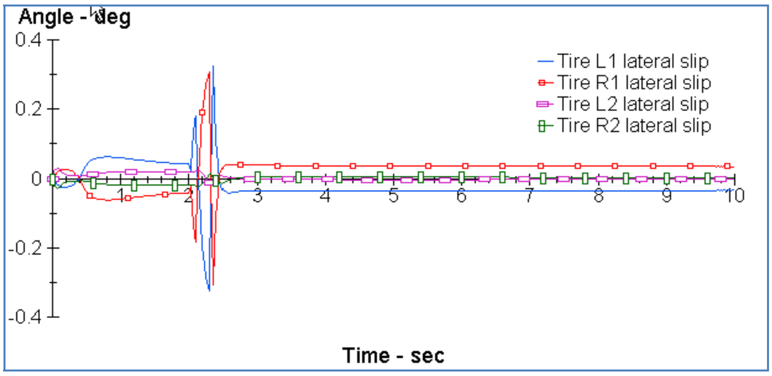

Fig. 8. Slipping angle of the tires.

In order to study the influence of the bushings to the wheel guidance, the lateral position of the vehicle after stopping is evaluated. The vehicle with new dampers and bushings is compared with the vehicle with new dampers and worn bushings.

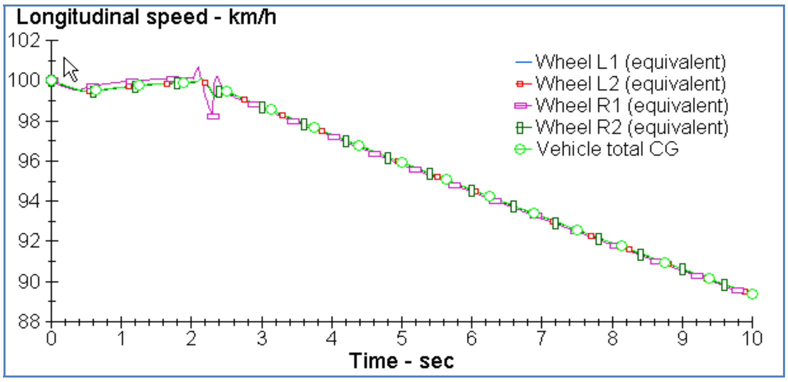

Fig. 9. Braking time beginning from the speed 100 km/h.

Furthermore a vehicle with worn bushings just on the left side is added to the comparison. The results are presented in Tab.2. As expected, the directional stability of the vehicle is significantly influenced by the worn bushings.

Particularly the situation, in which the vehicle has worn bushings just on one side (e.g. after some reparation) is very dangerous, since the driver has to compensate the lateral motion with the steering.

Tab.2. Lateral position in meters of the vehicle after stopping from 100 km/h for different bushing conditions on the front axle and new dampers.

New rubber bushings	0. 009
Defective rubber bushings	0.27
Defective rubber bushings (left)	2.72

The second series of simulation experiments deals with the condition of both axles. The worn or defective dampers are installed on both axles. The simulation results are summarised in Table 3.

Tab. 3. Stopping distance in meters from 100 km/h for different shock absorber and bushing conditions on both axles.

Physical conditions of dampers	100%	50%	30%	0%
New rubber bushings	46.6	46.9	47.8	55.5
Defective rubber bushings	46.6	46.9	47.8	58.8

Similarly to the previous results the state bushings have the influence just for the defective dampers. The increase of the stopping distance is about 20 percent, what is also the value often mentioned in the literature. Figure 5 presents the longitudinal tyre forces and Figure 6 the vertical tyre forces on all four tyres during the stopping manoeuvre. It is evident that the wheels often loose contact with the road surface (zero vertical force) during the manoeuvre.

CONCLUSIONS

This paper presents a model of a lower middle class passenger vehicle with elastokinematics on the front axle. The simplified models of rubber bushings were used. In order to study the influence of the worn or even defective shock absorbers and bushings the new parameter sets have been defined. This effort results in a set of models with the same structure and with different parameters.

The simulation experiments indicate that the worn bushings have a significant influence on the results with defective shocks. However, the vehicle lateral stability is influenced by worn bushings even for new dampers. It should be also noted that the vehicle without anti-lock brakes stops in 47.4 m from 100 km/h in perfect conditions and in 48.5 m with the defective dampers and worn bushings. It indicates that the influence of the worn components on the performance of the vehicle with anti-lock brakes is more significant than without anti-lock brakes.

The parameter sets origin from the literature; however the current work is focused on the preparation of the experiments on a test-rig, which should deliver more precise model and parameters of the rubber bushings.

Further evolution of the model structure is expected in adding the steering substructure. It allows to perform experiments connected with the lateral dynamics, such as braking during cornering.

LITERATURE

1. *Valášek, M., Vaculìn O. and Kejval, J., 2004*. Global Chassis Control: Integration Synergy of Brake and Suspension Control for Active Safety, 'International Symposium on Advanced Vehicle Control, AVEC 2004, Arnhem, pp 495-500.

2. P.Munaretto, M.Velardocchia, N. Riva, E. Suraci, N.Arborio." Vehicle Dynamics And Stability Analysis With Matlab And Adams Car.*,*

3. Automotive Handbook, Edited by Bosch, 4th Edition, ISBN 1-56091-918-3, Distributed by SAE Society of Automotive Engineers, USA.

4. Vehicle Dynamics and Simulation 2000, Proceedings of SAE2000 World Congress, Detroit, Michigan, USA, March 6-9, 2000, SP-1526

5. S. Matsumoto, H. Yamaguchi, H. Inoue, Y. Yasuno, "Improvement of Vehicle Dynamics Through Braking Force Distribution Control", SP-920645