Modelling and Simulation of the Motor Vehicle Suspension

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***Abstract*—In this paper some results regarding the experimentation, the modelling and simulation of the motor vehicle suspension of Logan type are presented. The experimental testing of the performances of this damper is made with Spider8 device. Then, a mathematical model is adopted to estimate the behaviour and the performances of the Logan damper, experimental tested in MATLAB/Simulink. The model coefficients are established from the experimental data of the Logan damper. The simulation results are compared with the experimental data. This comparison validates the model and the Logan damper parameters measured in experimental testing phase.**

***Index Terms*—Logan damper, modelling, parameters estimation, simulation, testing.**

I. INTRODUCTION

With a view to establish the suspension and damper dynamic response, the suspension of Logan motor vehicle was equipped with the dumper gifted with tensmetric marks and was made the experimental base structure of the Logan damper. The estimation of the mathematical model parameters is realized based on the damper experimental data. The results of the simulation in MATLAB/SIMULINK (based on the obtained model) are compared with the experimental data. This comparison validates the model and the parameters measured in the phase of Logan damper experimentation. For the simulation of the Logan damper behaviour must be developed a model which reproduces him as much as minute. An experimental testing mechanism is assembled for determining the functional properties of the Logan damper and also to obtain the dynamical data necessary for the estimation of the model parameters. Logan damper is fixed into an automatized Testing Mechanism, Spider8.

II. LOGAN DAMPER EXPERIMENTATION. ESTABLISH OF STATIC RESPONSE

II.1. Spider8 - System for numerical measuring of mechanical values

Spider8 is an electronic system for numerical measuring of the analogical data, specialized for numerical acquisition of the mechanical values such as: strains, mechanical voltages, pressures, accelerations, velocities, movements, temperatures. The device is scheduled with the possibility to measure the voltage analogical signals.

Spider8 is connected by USB or by a parallel port RS232 at the computer. The acquisition system contains the specialized modules for measuring some mechanical values.

Each measure channel has its own A/D (analogical/digital) converter, which can be setted at sampling frequency of 0,1 … 9600 samples/second. The converters work in parallel, being synchronised by the measuring system, having the possibility of simultaneous acquisition on the 8 channels.

II.2. Damper with tensmetric marks

To establish the strain characteristic, the variant of directly determination of the strain developed in the damper cane is chosen. An assembly with four tensmetric marks of LY5mm/120 Ohm type, applied on the driven cane at about 5mm of the upper shoulder was realized.

The damper equipped with four tensmetric marks, in complete bridge, is presented in figure1. The standardization, as strain transducer, of the damper, was realized on Universal Machine of Mechanical Tests of P50 type existing at Faculty of Electromechanical Engineering from the University of Craiova, using the strain transducer Hottinger, of U2B 10kN type. The standardization was made in the range of ± 1500N, by direct comparison method, for the ranges, traction and compression, by applying known strains measured with Hottinger transducer of U2B 10kN type.

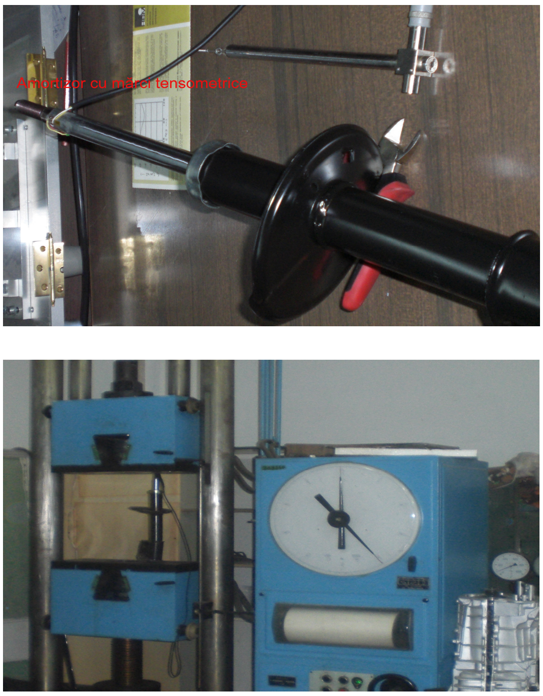


Fig. 1 Damper with tensmetric marks for measuring the traction /compression strains

III. ESTIMATION OF THE DYNAMIC RESPONSE OF LOGAN MOTOR VEHICLE SUSPENSION

III.1. Tests preparation and processing

The measure equipment and the used transducers are: Spider 8 acquisition system, NEXUS 2692-A-0I4 signal conditional, Bruel & Kjaer accelerometer of 4391 type (3 pieces), W50 inductive transducer of linear drive, damper with tensmetric marks and IBM ThinkPad R51 notebook.

The tests were made at SC REDAC SRL Craiova, on tests stall for ITP of MB6000 Beissbarth – Germany type, having: oscillating platform, display panel, reels for brake space verification.

The position of the measuring transducers was chosen taking into account the optimal measuring of the following characteristic parameters for the motor vehicle suspension:

-developed strain in the damper cane;

-damper drive (W50 transducer was used, parallel positioned with the cane damper, inside the suspension arc)

- acceleration on the vertical direction of front bridge (AccV accelerometer positioned on the damper frame, on the vertical direction, was used)

- horizontal - longitudinal acceleration of front suspension bridge (AccOL accelerometer positioned on the damper frame, on the horizontal-longitudinal direction, was used)

- acceleration on the vertical direction of the oscillating platform.

In figure 3 is represented the positioning of the measuring transducers on front suspension.

In figure 4 is represented a detail regarding front suspension of Logan motor vehicle and the positioning of the measuring transducers.

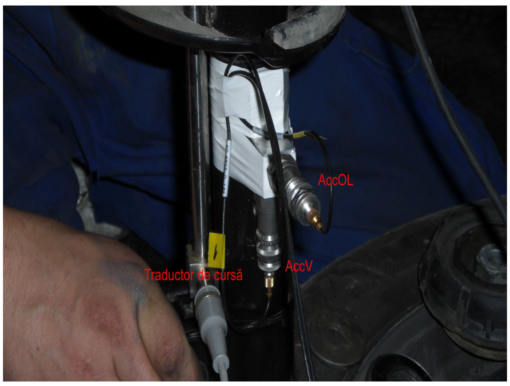


Fig. 3 The positioning of measuring transducers – detail

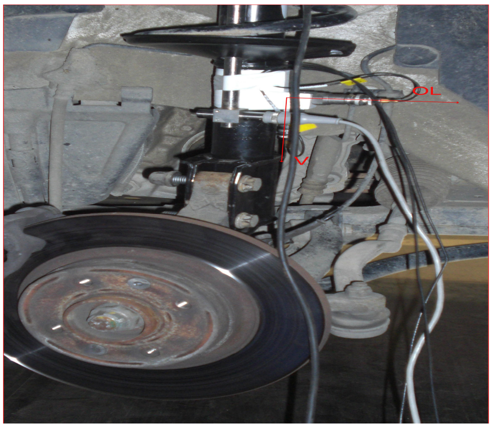


Fig. 4 Detail regarding the suspension, the positioning of the transducers and of front wheel on the oscillating platform

The measurements were made in conditions of oscillating movement generated by the left oscillating platform. The estimation of the dynamic response was made on left wheel equipped with measuring transducers.

The sampling rate of the Spider8 data acquisition system was of 2400 samples/second.

The following parameters were recorded: the damper drive (Crs (mm)), the strain inside the damper (F(N)), acceleration on the vertical direction, at damper level (AccV(m/s2)), acceleration on - horizontal – longitudinal direction, at damper level (AccOL(m/s2)), acceleration on the vertical direction, at oscillating platform level (AccVP(m/s2)).

After each test, the acquisitioned data were viewed and stocked in data files of ASCII type, for future processing.

III.2. Experimental data processing

A „PrelVib.tst" program to establish the damper and Logan motor vehicle suspension frequency characteristics was realized using TestPoint programming environment. (Fig.5).

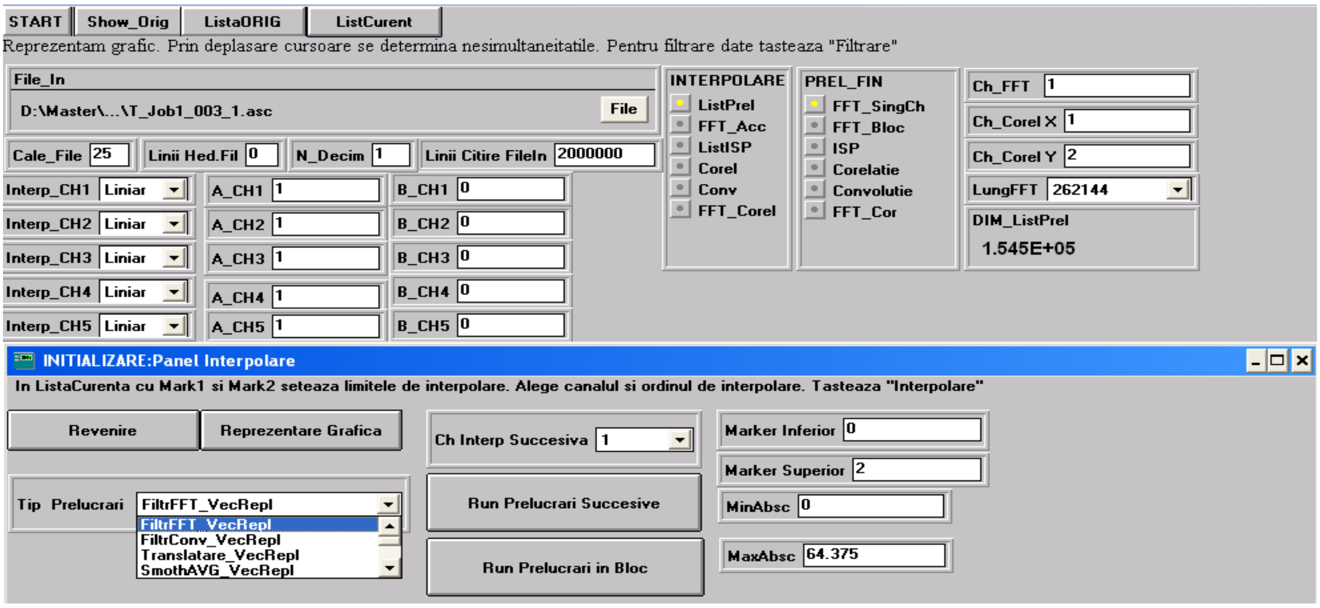


Fig. 5 Main panel of „PrelVib.tst" program

III.3. Time domain analysis

Three pulses of oscillator movement generated by the oscillating platform were recorded.

In Fig. 7 are presented the recorded characteristics and in Fig. 8 is represented the first pulse of the recorded characteristics.

There been determined the efficient values (RMS) of the measured parameters, for two interest areas: constant frequency and acceleration area of oscillating platform and decreasing area for frequency and acceleration of oscillating platform, of maximum amplification of the oscillating response of the suspension system.

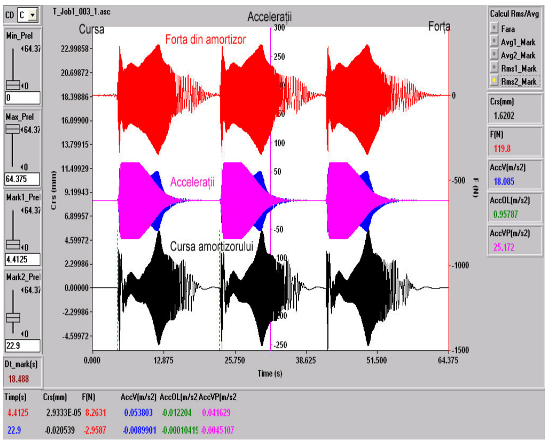


Fig. 6 Original recording for excitement front left wheel

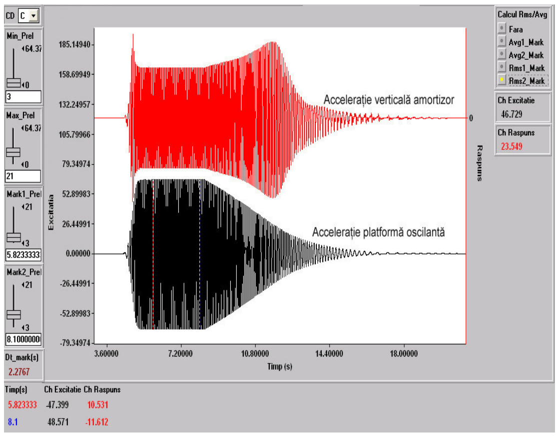


Fig. 8 Original recording AccV/AccVP

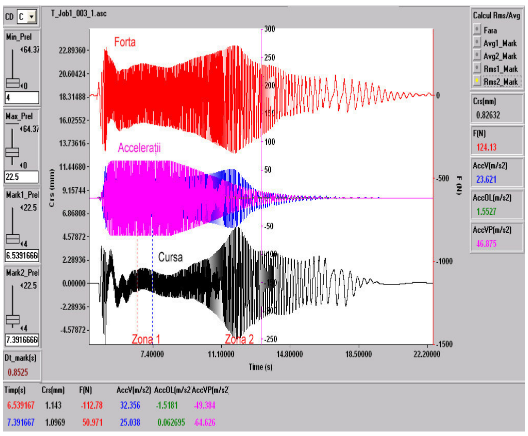


Fig. 7 Zoom recording first impulse

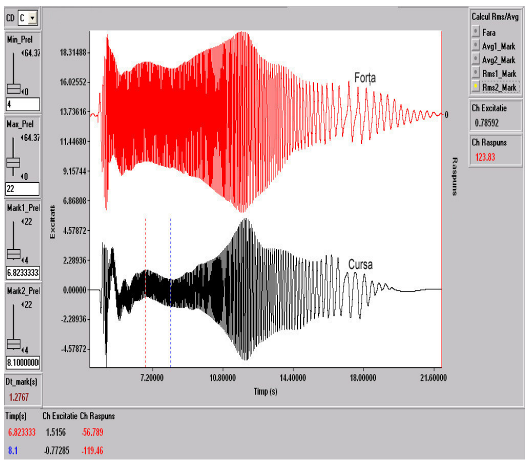


Fig. 9 Original recording F/Crs (first impulse)

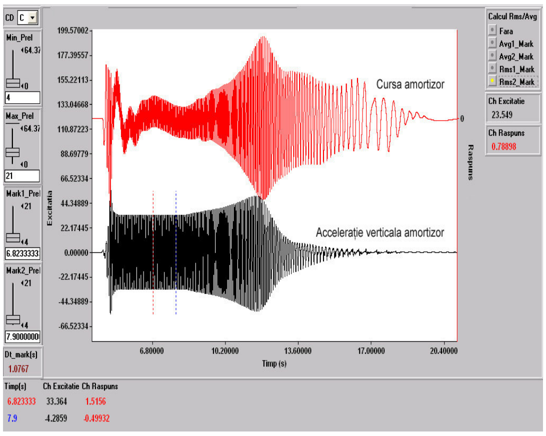


Fig. 10 Original recording Crs/AccV

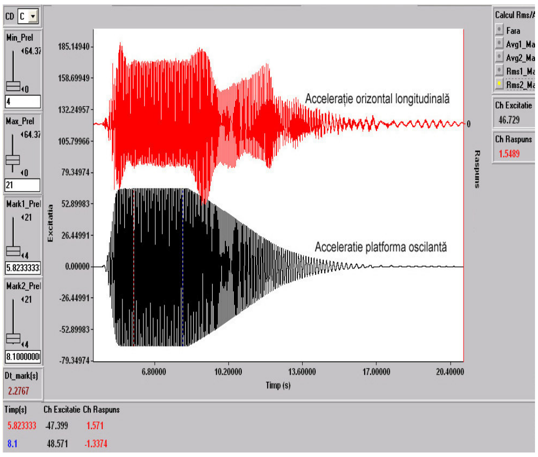


Fig. 11 Original recording AccOL /AccVP–zoom first impulse

In Fig. 8-11 are presented the pairs of charactersitics which manage to establish the response functions in frequency field. The characteristics presents a zoom at first oscillation pulse.

III.4. Frequency domain analysis

Frequency analysis of the established parameters was done. For a recording effectuated with the sampling frequency of 2400 Hz/channel and a period of 64.37 s, a resolution in frequency of 9,1mHz corresponds. In Fig.13 are represented the spectral characteristics of the measured parameters. From these characteristics the interest areas can be observed. The two cursors are positioned in respective areas.

Calculus of the response functions in frequency

In Fig. 14a is represented the response function in frequency of the suspension. The cursors are positioned in the two marked areas.

By comparing the data and the graphical representations of FFT (Fig.12) and ISP (Fig.13a), can be observed a very well correlation of the analyses made in time and frequency domain.

In Fig. 14 and 15 are presented the response function in frequency of the damper. The cursors are positioned in the two marked areas previous mentioned. Similar with the response analysis in frequency of the suspension, by comparing the data and the graphical representations of FFT (Fig.12) and ISP (Fig.13b), can be observed a very well correlation of the analyses made in time and frequency domain.

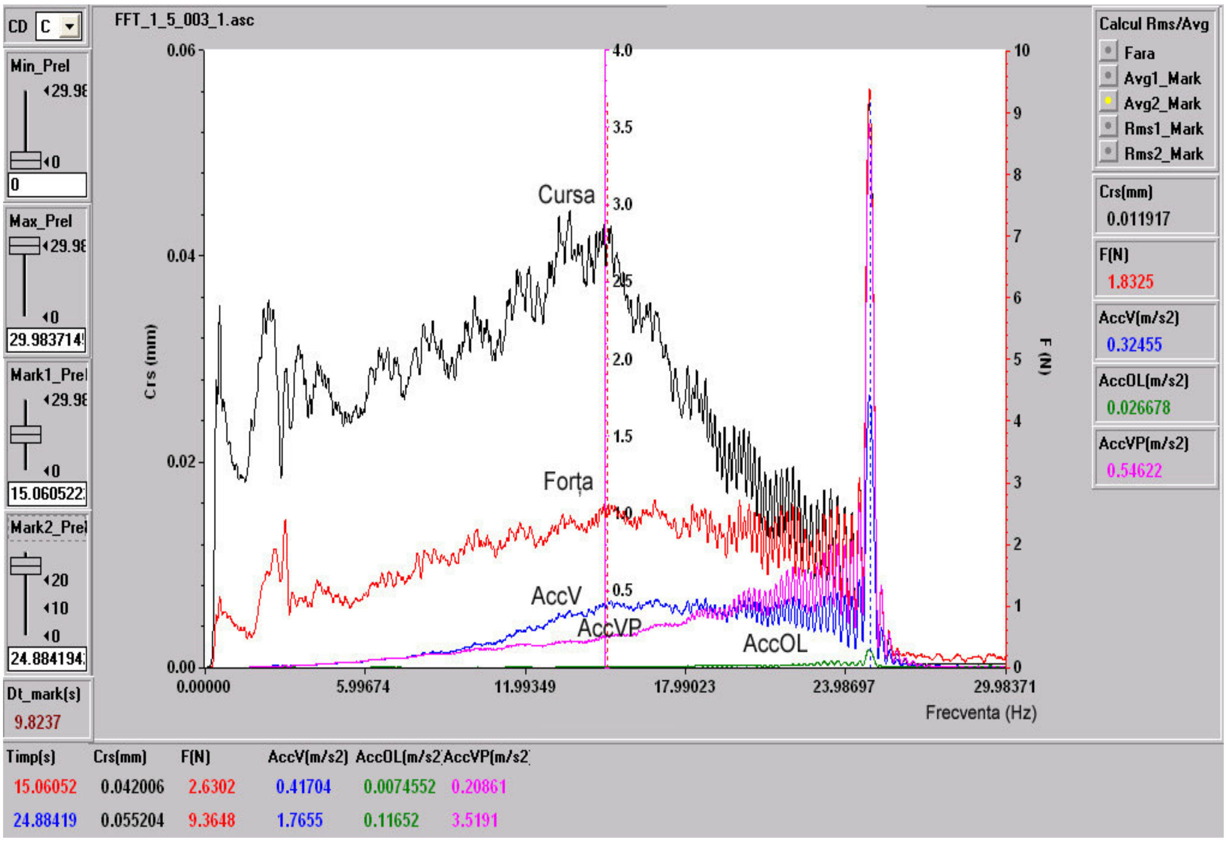
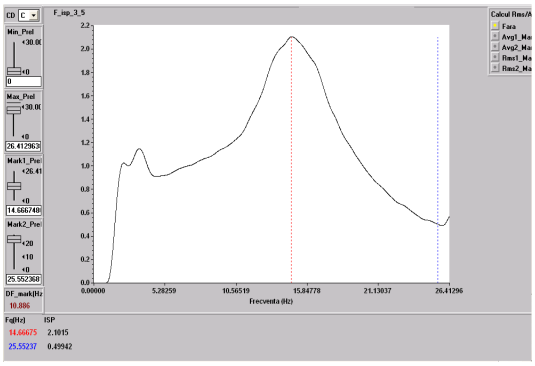
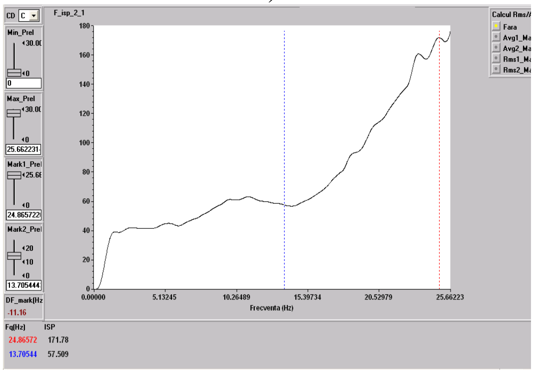


Fig. 12 Spectral characteristics of measured parameters



a)



b)

Fig. 13 Frequency response function of the suspension a)AccV(m/s^2) /AccVP(m/s^2); b) F(N)/Crs (mm).

IV. MATHEMATICAL MODELLING OF THE SUSPENSION

IV.1. The mathematical model

The damper model must be continuous in all its components. The structural schema is presented in Fig.14. The force applied to this dynamic system depends on time variable t and is noted with F(t). In the absence of the mobile mass and, therefore, of the inertia forces, this force F is equilibrated by three components described by functions in which the independent variable is the displacement x(t) or the speed v(t)=dx/dt. To simplifying the writing, in the following is omissible the time variable, but its presence must be connotation. The two components which equilibrate the force F are: the linear elastic component fe(x) determined by the spring characterised by the rigidity coefficient k0; the linear viscous component fv(x) characterised by the viscous coefficient c0. The hysteresis component, hz(x)= α z, is characterised by the hysteresis coefficient α and by the nonlinear function of hysteresis z(x).

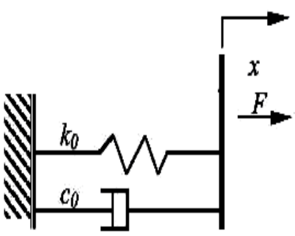


Fig. 14 Vehicles suspension: structural schema

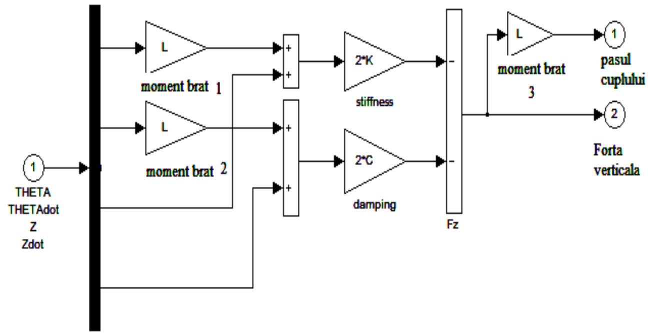


Fig. 15 Simulink model for vehicles suspension

When the mobile mass is zero, the inertia forces disappear and the equilibrium equation of the forces, expressed throw the three components, $F=f_e+f_v+hz$ is explicated by:

$$F = c_0\dot{x} + k_0 x + \alpha z \qquad (1)$$

In relation (2) the histeresis function z(x) is obtained as a solution of the following equation:

$$\dot{z} = -y|\dot{x}||z||z|^{n-1} - b\dot{x}|z|^{n} + a\dot{x} \qquad (2)$$

IV.2. Simulink model

Transcription in Simulink of the linear part L from the figure 15 requires only few calculus blocks: a derivative block with amplifier c_0 which has the input x and the output $c_0 dx/dt$; an amplifier block k_0 which has the input x and the output $k_0 x$; a sum *block* which totals F, $k_0 x$, $c_0 dx/dt$ and az.

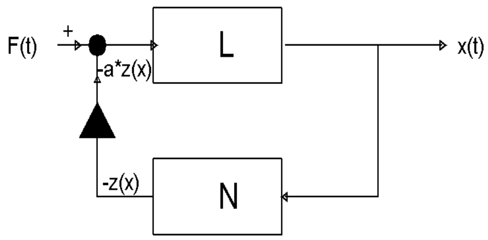


Fig. 16 Structural schema of the vehicles suspension

Simulink model of the nonlinear equation offers the damper specific loop and is described by the differential equation (2) from which results that the output z(x), for n=2 and y=z, is calculated by the relation:

$$z = -\int[|\dot{x}||z|z^2 + b\dot{x}|z|^2 - a\dot{x}]dt \qquad (3)$$

The input signal of the nonlinear block N is the displacement x (which represents the output of the entire model) and is received from the output of the linear block L. The speed $\dot{x}$ from the equation (3) is obtained by derivation the input x of the nonlinear block N, that is v(t)=dx/dt.= $\dot{x}$.

The relation (3) is the basis of the SIMULINK model of the nonlinear component N. The connections between Simulink blocks of the entire system, realised accordance with (1) and (3) are presented in Fig. 17. Two signal generators are used for simulation the time variation of the model input force F(t).

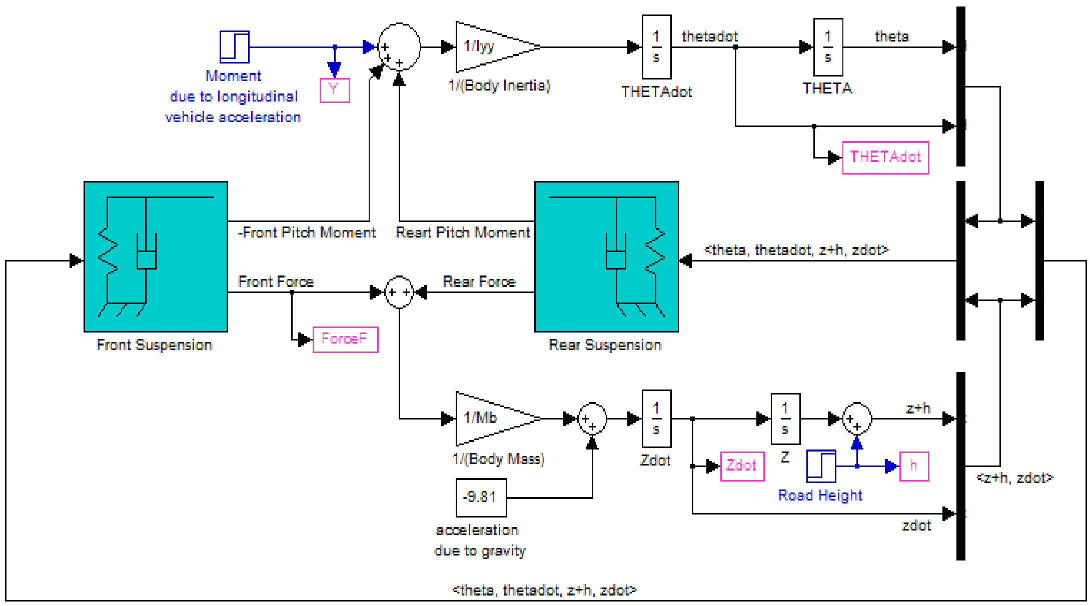


Fig. 17 Suspension model in Simulink

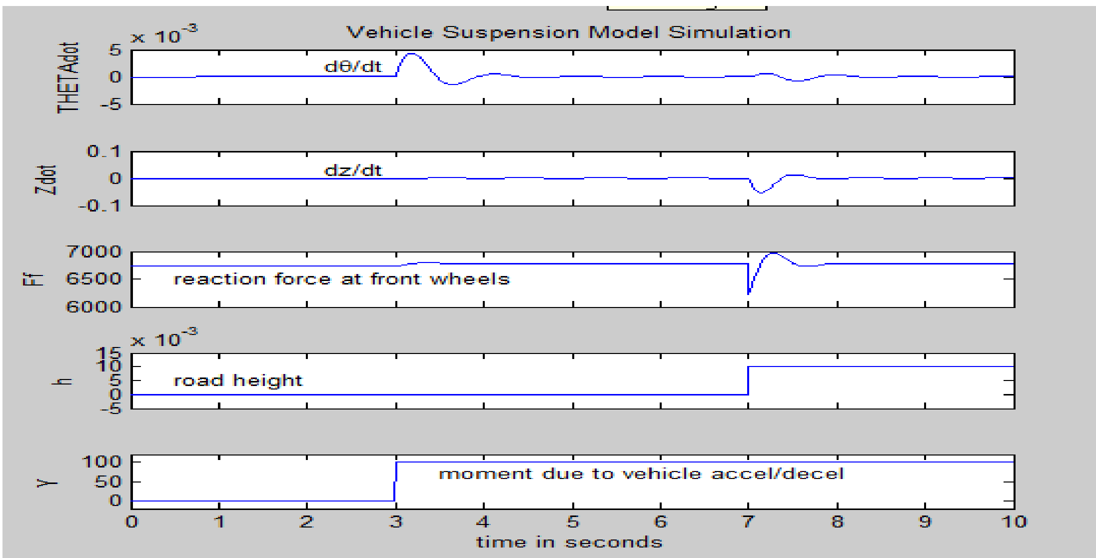


Fig. 18 Model simulation results

V. CONCLUSION

Suspension simulation results (Fig.18) were compared with the responses obtained in damping experimental testing phase (Fig.8-11). A good concordance between experimental data and those given by simulation schema from Fig 17 is resulted. This manage to the conclusion that the model (on which is based the Simulink implementation from Fig. 17) can be accepted for computer simulation, generally of the motor vehicle suspension and particularly of motor vehicle of Logan type.

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