EXPERIMENTAL RESEARCHES REGARDING THE ACTIVE SAFETY SYSTEMS FOR PASSENGER CAR

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Keywords: active safety, ABS, vehicle dynamics, Matlab-Simulink, model, simulation

Abstract In this study were developed experimental researches regarding the active safety systems for passenger cars. In order to validate the ABS/ASR system working algorithm and to accentuate the influences over the braking or starting processes with and without ABS/ASR, a planar dynamic model was designed for a single wheel of the passenger car. This simplified model has two inertial elements: a wheel in rotation and a mass in translational movement (the "quarter" vehicle).

1 INTRODUCTION

Many factors influence the safety of vehicle during driving in the context of nowadays traffic [2]:

the general condition of the vehicle (equipments, tire condition, wear phenomena);

meteorological conditions, road condition and the traffic conditions (for example: lateral wind, road surface or the traffic density).

The passenger car safety represents its capacity to prevent accidents and to diminish the consequences of an accident produced by other causes than technical break down. This safety comprises two major categories:

- Active safety;
- Passive safety

The active safety consists in prevention or avoidance of some accidents that take place as a consequence of an improper operation of the passenger car, and the passive safety consists in reducing the effects of an accident on passengers.

The main characteristic of active safety systems consists in maintaining the directional stability and maneuverability of the passenger car in critical rolling conditions as: wheels locking on a slippery surface, skidding in curves, the unexpected appearance of some obstacles.

2 THE MODEL FOR ABS (ANTI-LOCK BRAKING SYSTEM) SIMULATION

2.1 The dynamic model of ABS

To check the ABS working algorithm and to emphasize the different influences on the braking process, with and without ABS, a planar dynamic model for a single wheel of the vehicle was conceived and used. The selected model has two inertial elements: a wheel and a mass in translational movement (the vehicle).

The influences of the suspension and direction mechanisms weren't explicitly considerate [4]. Also were neglected the jerk and jumping movements of the wheel, respectively the lift up and pitch movements of the translational mass. These simplifications were realized deliberately to highlight the anti-lock braking system parameters that influence the braking process. In these conditions, the dynamic model has only two degrees of freedom: the wheel rotation around the spindle and the translation of the mass sustained by this wheel (including the wheel mass) on the travelling (longitudinal) direction [5].

2.2 The Simulink model of ABS

Simulink is a work module of the general mathematical calculus program Matlab (Mathworks Inc.). It is suitable for the simulation of technical systems because it has some very valuable qualities [3]:

- It allow the description of the modeled system using block diagrams interconnected with signal lines; from here results the ease in creation, understanding and use.
- The block diagrams can be hierarchically grouped, which permits the description of some subassemblies and assemblies of great complexity.
- The writing of the algebraic and differential equations with initial values that constitute the mathematical model of the system is done automatically.
- For solving the mathematical model more advanced methods of numerical integration are available.
- The simulation results, obtained as a function of time, can be graphically represented in different ways.
- The results obtained for one simulation can be stored in Matlab clipboard memory in order to realize further analysis and comparisons

In figure 1 it is presented the main diagram of the Simulink model realized for the simulation of the ABS operating mode.

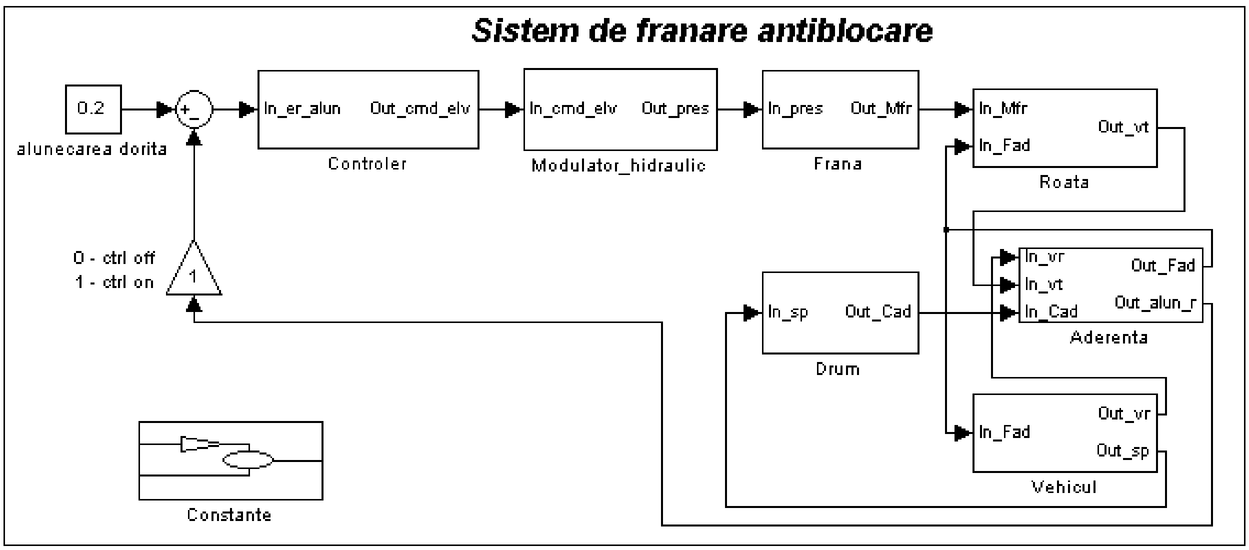

Fig. 1. Diagram of the Simulink model for ABS simulation

The blocks that compose it are defined to permit the identification and understanding of the ABS functioning. The “Wheel” and “Vehicle” blocks correspond to the two degrees of freedom of the dynamic model – wheel rotation and “quarter” vehicle translation. These two movements are connected through the grip between the wheel and the road (“Adherence” block) that depends on the road properties defined in the “Road” block.

The comparator (the round block from the left side of the figure) calculates the difference between the desired values of the slip (the “Desired Slip” block) and the real slip (calculated in the “Adherence” block). Using this difference, the “Controller” block that simulates the operation mode of the adjustment algorithm implemented in the ABS computer will establish what kind of command must be executed by the ABS hydraulic assembly (modeled by “Hydraulic Modulator” block). The pressure generated by this is finally applied to the brake (modeled by the “Brake” block).

“Ctrl off / Ctrl on” block was introduced in the inverse connection path (to enable or disable the feedback loop) in order to simulate with the same model both an anti-lock braking system (ABS) and a classic braking system (without ABS).

Even if it is very simple, the model was realized in a systemic vision, chasing the accentuation of the functional links between the different components of the ABS.

2.3 Braking simulation when the vehicle is running on a road with dry asphalt

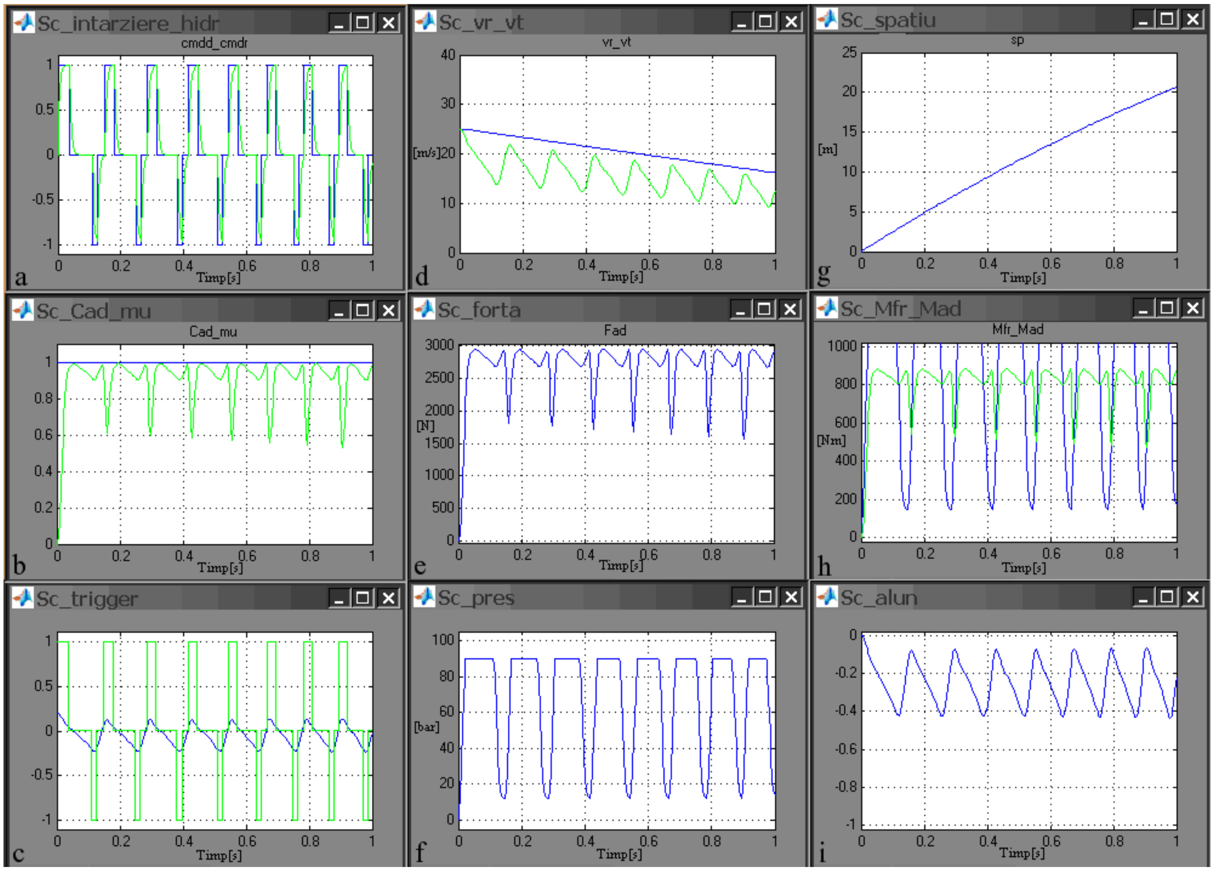

Fig. 2. Brake simulation results. a – hydraulic delay; where it can be seen the difference between the electro-valve command without the hydraulic delay and electro-valve command with the hydraulic delay; b – road adherence coefficient and the utilized adherence coefficient; c – electro-valve command and the difference between the desired slip and the realized slip; d – the evolution in time of the real speed and of the theoretical speed; e – adherence force. f – pressure variation in the hydraulic circuit; g – distance traveled as function of time; h – braking moment and adherence moment; i – slip variation.

Simulation parameters was:

ABS on;

Three states controller (able to increase, maintain or decrease the braking pressure);

The maximal pressure in the hydraulic circuit is 90 bars;

System delay equal with 0.005 s;

Vehicle mass equal with 1200 kg;

The moment of inertia of the wheel equal with cu 0.75 kgm2;

The braking initial speed (from which starts the braking) is 25 m/s;

The road surface has an adherence (grip) coefficient equal with 1 corresponding to a dry asphalt road;

Hydraulic gain equal with 5000 bar/s.

3 EXPERIMENTAL TESTS REGARDING THE PERFORMANCES OF THE BRAKING SYSTEM

To find the ABS behavior and performances during vehicle braking, numerous experimental records were made, in different conditions. For easier identification and data processing, the records were grouped on sets (S1...S3) and probe (P1...P11). Further, the set S2 will be presented. In this set, the following tests [1] were realized (table 1).

Set no.	Test no.	Test description
S2	P1	Linear braking (with ABS) on dry asphalt, with the engine out of gear
	P2	Linear braking (with ABS) on a surface with different adherence left/right.
	P3	Linear braking (with ABS) on a surface with different adherence left/right.
	P4	Linear braking (with ABS) on a surface with dry cubic stone.
	P5	Linear braking (with ABS) passing from dry cubic stone on dry asphalt.
	P6	Braking when turning right (with ABS) on dry asphalt.
	P7	Linear braking (with ABS) on dry asphalt.
	P8	Linear braking (without ABS) on a surface with different adherence left/right.
	P9	Braking when turning right (without ABS) on dry asphalt.
	P10	Linear braking (without ABS) passing from dry cubic stone on dry asphalt.
	P11	Linear braking (without ABS) on dry asphalt.

The tests described in table 1 were realized on the testing ground from DAEWOO AUTOMOBILE ROMANIA S.A. CRAIOVA.
Experimental data was acquired on an experimental ABS system fitted on a Daewoo Nubira car.
For measuring and recording the quantities, it was utilized a complex data acquisition system. Its disposal scheme is presented in figure 3.

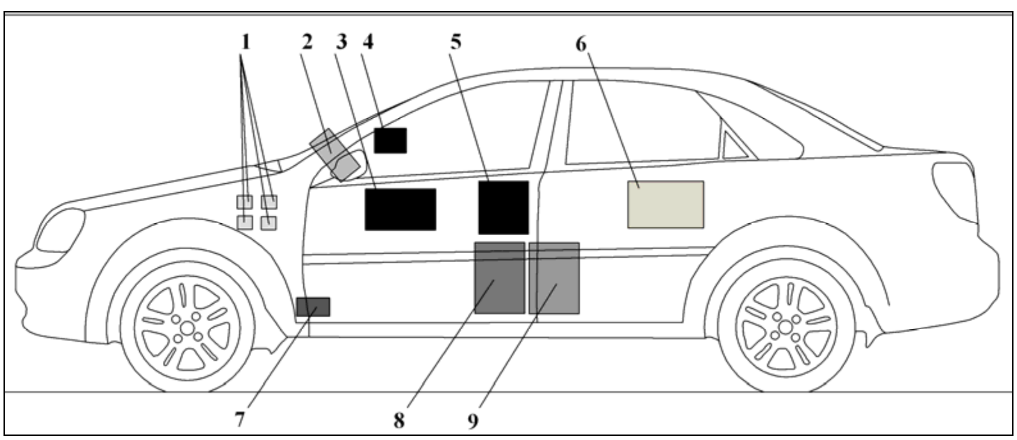

Fig. 3. Disposal scheme of data acquisition system components: 1 – pressure sensors; 2 – sensor for measuring the angle and the torque on the steering wheel; 3 – speed sensor (Datron); 4 – display; 5 – data logger; 6 – laptop; 7 – sensor for the force on the braking pedal; 8 – signal amplifier; 9 – acquisition data device

The scheme presenting the utilized equipment interconnections, during the experimental research, is presented in figure 4.

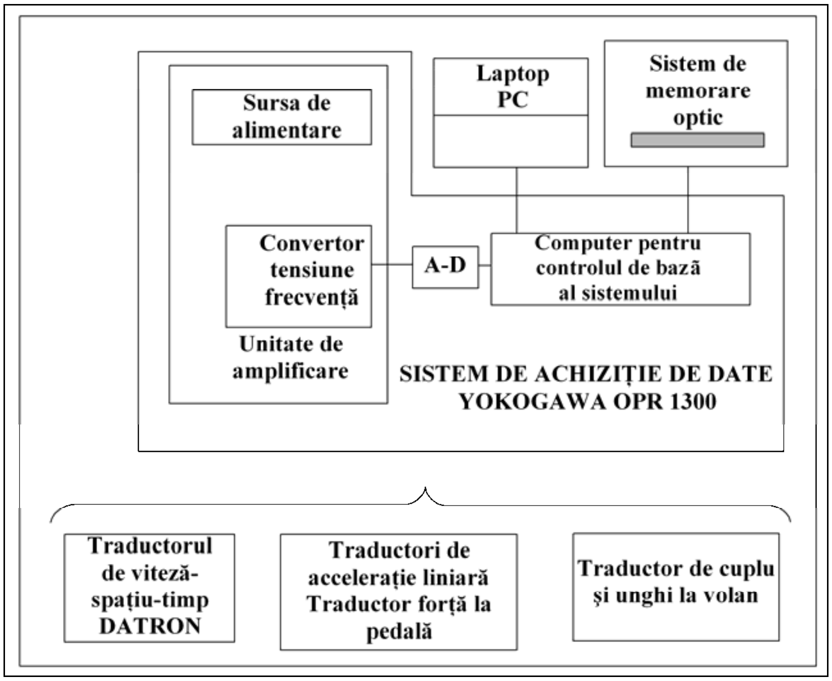

Fig. 4. Interconnecting scheme of the equipment utilized during the experimental research

With the equipment presented above were measured the following quantities:
With the DATRON system:
- Velocity;
- Traveled distance ;
- Acceleration;
- Time.

With the Yokogawa system
- Channel 1 – the pressure in circuit 1 (on the exit from the main braking cylinder);
- Channel 2 – the pressure in circuit 2 (on the exit from the main braking cylinder);
- Channel 3 – the pressure in cylinder 1 (the caliper from front-left wheel);
- Channel 4 – the pressure in cylinder 2 (the caliper from front-right wheel);
- Channel 5 – steering wheel angle;
- Channel 6 – steering wheel torque;
- Channel 7 – actuation force on the braking pedal.

For each probe, the testing conditions, different in at least one aspect, were noted.
From the realized records, the braking test S2-P1 (Linear braking with ABS on dry asphalt) will be presented further. This probe was performed in the following conditions:
Linear braking, with warm brakes;
Adherence coefficient on the left: 1.0 (dry asphalt);
Adherence coefficient on the right: 1.0 (dry asphalt);
The initial vehicle speed (at which starts the braking): 82.2 km/h.
Graphic evolution of the sizes measured is shown in figure 5 and 6.

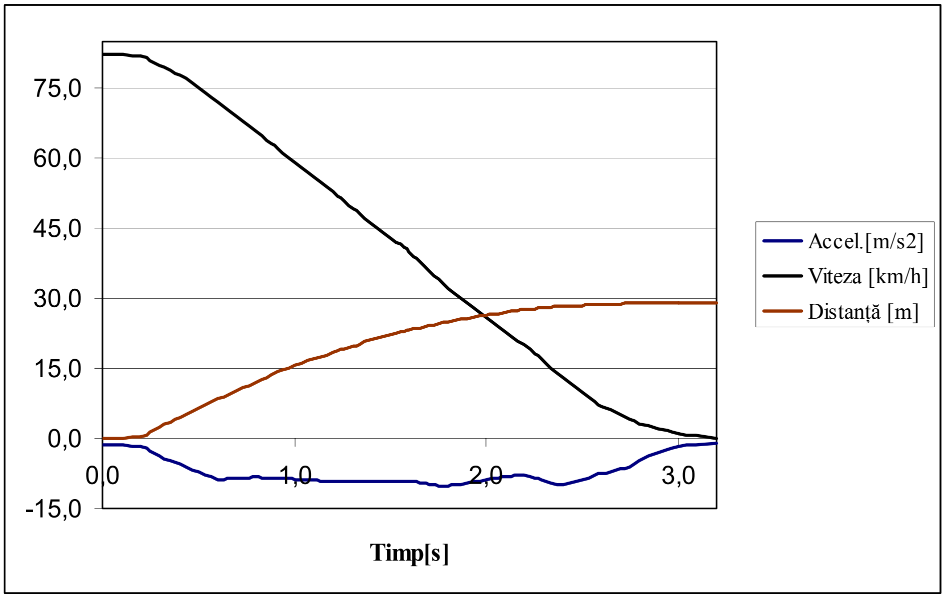

Fig. 5. Linear braking (with ABS) on dry asphalt. Acceleration, speed and distance measured with the DATRON system

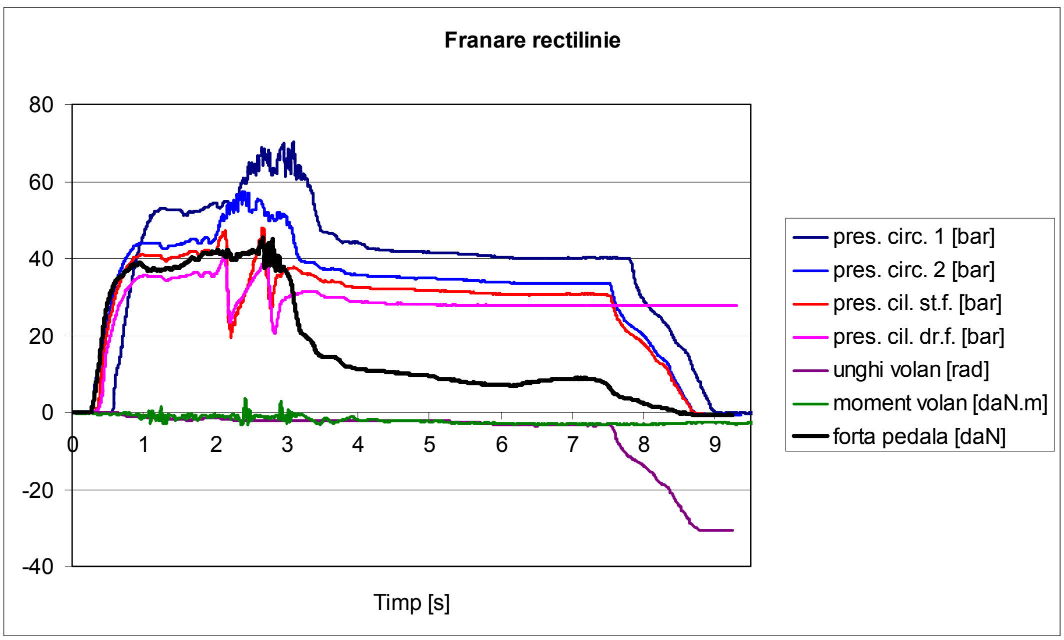

Fig. 6. Linear braking (with ABS) on dry asphalt. The pressure in the braking circuit, the pressure in the braking cylinder, steering wheel angle, steering wheel torque and the force on the pedal measured with the data acquisition system.

4 THE COMPARATIVE ANALYSIS OF THE THEORETICAL AND EXPERIMENTAL RESULTS

Part of the experimental records, made in controlled and well known conditions, was used to calibrate the model (i.e. to fine tune its input values as gain, delays, etc.) and to validate it. Then, results obtained by simulation were compared with the other experimental results. Figures 7 and 8, respectively 9 and 10 show pairs of similar results, obtained both by simulation and experiments on proving ground.

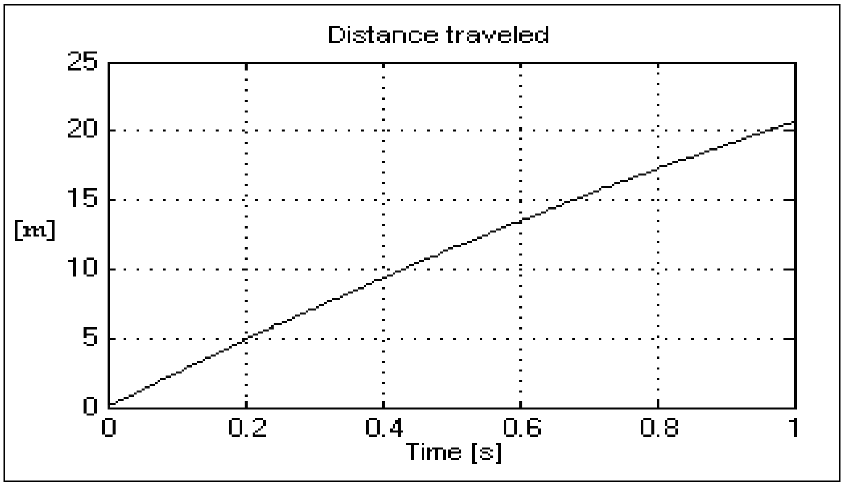

Fig. 7. Braking distance vs. time; braking on dry asphalt, simulation

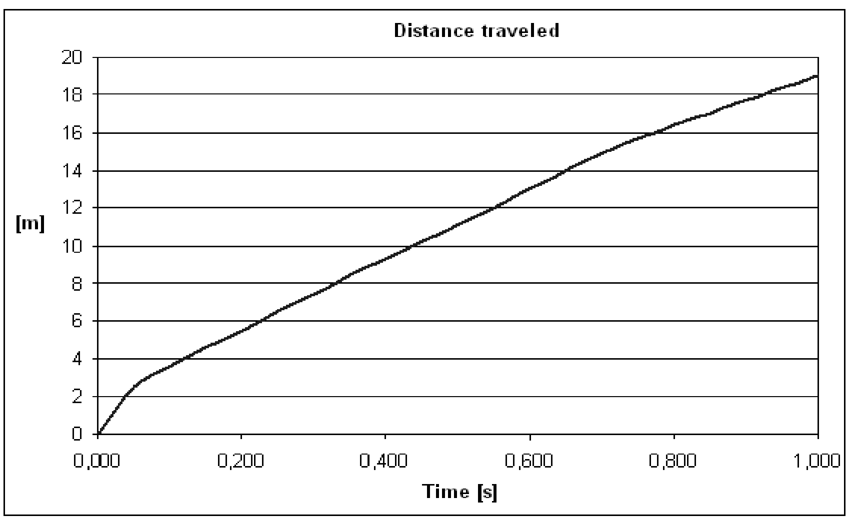

Fig. 8. Braking distance vs. time; braking on dry asphalt, experimental results

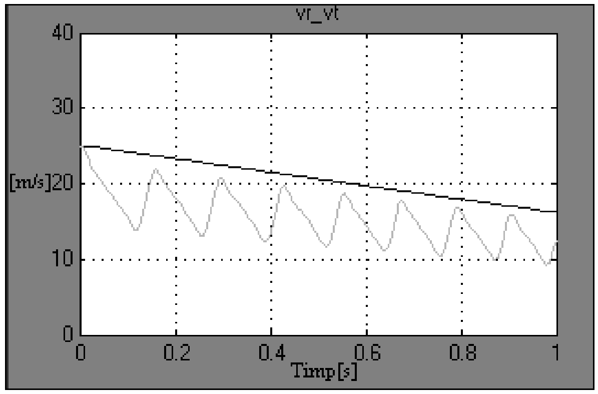

Fig. 9. Theoretical speed evolution and the real speed evolution; braking on dry asphalt

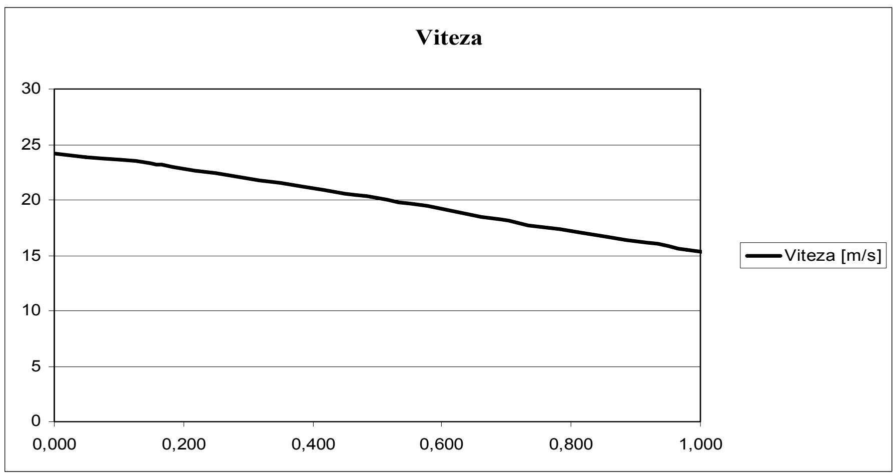

Fig. 10. The evolution of the measured speed; braking on dry asphalt

The experimental conditions for the braking process presented in figures 11 and 13 were:
Rectilinear braking (with ABS), with warm brakes;
Dry asphalt road;
The velocity from which the braking starts is 22.8 m/s.
The simulation parameters for the braking process simulated in figures 10 and 12 were quite similar:
Dry asphalt road (constant grip coefficient, equal with 1), for all the wheels;
The braking initial velocity is 25 m/s.
The vehicle mass is 300 kg per wheel.
The inertia moment of the wheel is 0.75 kg m2.
The maximal pressure in the hydraulic circuit is 90 bars;
Three states controller (able to increase, maintain or decrease the braking pressure);
Comparing the experimental results with the theoretical results obtained by simulation, it can be seen that the results obtained with the mathematical model have similar evolutions with those determined by measurements.
This proves that the simulation model realized and presented in this paper surprise accurately enough the phenomena related to the car wheel braking dynamics.

5 CONCLUSION

The technical solutions successes applied to the braking domain were followed by the bond of using anti-lock braking systems (ABS), at first for the heavy vehicles, and nowadays a real offensive trend to extend these systems on small and medium auto vehicles.

Even if there exists a lot of theoretical and experimental researches worldwide, the large number of factors that influence the braking process lead to the conclusion that the problems regarding this system still remain open for study.

Even if the ABS systems are already in the series production, with well known basic principles and layouts, the CPU algorithms used to adjust the brakes actuation have specific particularities for each producer, through each solution being followed the goal of carrying out all the performance criteria imposed by the actual regulations.

The main objective of this work was to realize a simplified mathematical model of the vehicle that permits the simulation of the braking process, able to reproduce with enough accuracy the ABS behavior. This goal was largely achieved.

References

[1] Beles, H. The research regarding the development of active safety for passenger cars in order to reduce the accidents with serious consequences, Doctoral thesis (in Romanian), “Transilvania” University, Brasov, 2007.

[2] Bosch R. GmbH Automotive handbook – 6th Edition, Plochingen, 2004.

[3] Matlab Simulink tutorial Modelling an Anti-Lock Braking System, 2007.

[4] Preda, I.; Todor, I.; Ciolan, Gh. Contributions to the simulation of vehicle longitudinal dynamics. In: Bulletin of the “Transilvania” University of Brasov, vol.12 (47), Seria A1, p.177-186, ISSN 1223-9631, Brasov, 2005

[5] Preda, I.; Ciolan, Gh. – Wheel-road interaction modelling. Proceedings of “CAR” International Conference, pg. 85-90, Pitesti, 1997.