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STUDIES ON THE BRAKING BEHAVIOUR OF THE VEHICLES USING NUMERICAL MODELS AND COMPUTERIZED SIMULATION

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Abstract: *The paper aims to evaluate the parameters which characterize the braking process of vehicles, using numerical models and computerized simulation, in the case of various loads and various rolling conditions, so that the drivers can become aware of these elements thus adapting their driving style at the specific driving conditions. The various features and states of the road determine the variation of the adhrerence coefficient, influencing the limit at which skidding appears as well as the behavior of the entire vehicle changes until reaching this limit. All these situations can become causes for incidents if the drivers do not evaluate them correctly. By evaluating the behavior of vehicles in each of the specific situations, the drivers will have additional information which will help them anticipate the limits and the behavior of the vehicles, thus driving within limits that will ensure their safety, their passengers' safety and the other drivers in traffic. The analytical numerical model developed using MathCad takes into account the geometric parameters of the vehicles and allows the analytical evaluation of the braking parameters of the vehicles taken into account for various driving situations, focusing on obtaining various results on braking parameters variations in relation to the tyre pressure, load on chassis, the state of the road, the type of tyres and the braking system. The computerized simulations have been done on CarSim, aiming to study the behavior of the vehicles during the braking process for various driving situations, thus highlighting the parameters whose variation determines the change in the braking parameters. The results were interpreted graphically, allowing a comparative study. Thus, in the situation when experimental data cannot be obtained, such in the case of vehicles still in design stages, the mathematical model, according to the number of freedom degrees given, can provide data which can characterize the braking qualities of vehicles.*

Key words*: vehicle, braking, numerical model, computerized simulation*

1. INTRODUCTION

On the extensive bibliography existing in the field, both books and scientific works published, tendency shows the development and use of the models physico-mathematical that astound possible variables in the use of motor vehicles, and which will enable a pragmatic interpretation of the results obtained.

In the specialized literature [4, 6, 8, 10-13, 15-17] are treated aspects with regard to the description of the physical phenomena in the braking process of motor vehicles, which may lay at the basis of the development of models of work which to capture a wide range of situations frequently encountered in the use of motor vehicles and by which to give results relating to road safety, with the influence of the various parameters for the use of motor vehicles, in their behavior when traveling in the cornering lights. Due to concerns about the continuous researchers in the field of the dynamics of motor vehicles and safety in use of them at the current time there are no results [5, 7, 9, 14, 18] experimentally obtained or by computerized simulation times of the mathematical model relating to the matters referred to above, to encourage their continuation, by capturing the concomitant emergence of as many variables that are likely to be encountered during braking of motor vehicles, respectively in practice their leadership. The scientific paper [7] investigates the coordination of active steering front and rear braking in the driver to assist system for vehicle yaw control. The paper [18] show the vehicle's mathematical model for braking dynamics considering the dependency of the grip coefficient between the tire and the road with the longitudinal velocity of the vehicle and the paper [5] indicates that the longitudinal dynamics has used to design the grip estimation algorithm processed by the Simulink models. The paper [9] introduced namely of hysteresis turntable-processes characterized in the brake system and dynamic relevant model of this effect for further application to the ABS and ESC algorithms control. In the work [14], shall be assessed from the point of view of mathematical antecollision speeds and the path of the vehicle in the framework of the braking process, surprised by the physical models.

Technical conditions for checking the efficiency in the braking system of the vehicles are laid down in the [19].

Knowledge by the driver of the vehicle behavior in different situations of braking, as well as the influence of the additional loading and environmental factors on the dynamics braking efficiency is a real necessity which allow the anticipation and prevent certain dangerous situations. Regardless of the degree of the performance of the braking system, the most important factor to carry out an effective braking is constituted by the driver and the capacity of the concentration and the reaction.

For the assessment of the behavior and took the car in the study, in the case of braking, have developed *analytical models of computing* in MathCad which take account of a number of parameters, specific to the vehicle and the environment for the use of his influence on the results. Numerical models follow:

- the variation of the braking distance depending on the condition of the rolling surface, in the case of using the summer tires;
- the influence of the ABS system on the braking distance, in the case of using the summer tires, on thedry rolling surface;
- the influence of the inclination angle longitudinal movement of the road on the braking distance, in the case of using the summer tires, on the dry rolling surface - in the case of ramp climb, respectively in the case of downhill a slope;
- the variation in the longitudinal and transversal maximum possible, depending on the additional loads of the car, in the case of use of the summer tires - for the rolling on the dry and wet surface.

Using the package software CarSim has *simulated the behavior of the cars* in the braking process in order to following:

- the variation of the braking distance according to the vehicle load for the dry and wet rolling surface, in the case of using the summer tires;
- the influence of the ABS system on the braking distance on the dry rolling surface in the case of using the summer tires.

2. DETERMINATION THE AXLES LOADINGS, IN THE CASE OF VARIOUS ADDITIONAL LOADS ON THE VEHICLE

Loading on the axles, depending on the additional masses (for changing the axle load the vehicle, are used bags filled with sand, each with the weight of approx. 50 kg) with which the software has been loaded onto the vehicle submitted for the tests (Citroën C4 1.6 HDI), were determined using the equipment of Periodical technical inspection line *(ITP)*, respectively the diagnostic suspensions with scales *Space APF 110*, controlled by the control unit of the *PFC Space 750* (Fig. 1), on the equipment of the *Center for Research in Engineering of Motor Vehicles and Transportation*, respectively the structure of its related research - the *Research Laboratory for the Analysis and Diagnosis of Motor Vehicles,* from the *Department of Automotives Engineering and Transports from the Technical University of Cluj Napoca.*

From the vehicle parameters take under study (Citroën-C4 1.6 HDI), in an unloaded situation, shall include the following information: vehicle unloaded mass, 1304 kg; tire size: 205/55/R16; tire type: summer; the tire inflation pressure: 0.22 MPa; the type of the braking system: disk/disk.

Fig. 1. Determination of the load on the front axle using the tool with the scales.

The positioning of the additional loading in the vehicle was carried out in such a way that the results obtained correspond to some situations frequently encountered in the use of vehicle. Thus, supplementary load has been entered in the luggage compartment of the vehicle, influenced the load on the rear axle (Fig. 2), and thus achieving a distribution approximately equal to braking force on the axle of vehicle.

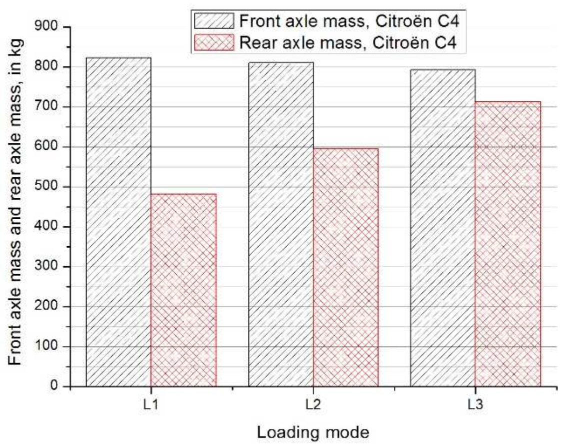


Fig. 2. The correspondence between the loading mode and the distributed mass between the axles for Citroën car (C4). L1 - Unloaded; L2 - Loaded (100 kg in the trunk); L3 - Loaded (200 kg in the trunk).

As a result of the measurements made on the weighing, may determine the coordinates of the center of gravity of the vehicle, for the different situations of loading. Thus, on the basis of the relations (1) [2, 4, 6, 8, 11, 12, 16, 17], result as examples, data presented in Table 1 for vehicle Citroën C4,

$$a = \frac{G_2}{G_a} \cdot A; \quad b = \frac{G_1}{G_a} \cdot A , \qquad (1)$$

where: G_a is the total weight of the vehicle ($G_a=G_1+G_2$); G_1 - distributed weight on the front axle of the vehicle ($G_1=m_1 \cdot g$); G_2 - the weight of the allocated to the rear axle of the vehicle ($G_2=m_2 \cdot g$); G_1 and G_2 are the values experimentally determined (see Fig. 2); g - gravitational acceleration; a - distance from front axle to the center of gravity of the vehicle; b - distance from the rear axle to the center of gravity of the vehicle.

Table 1

The coordinates of the centre of gravity, in the case of Citroën C4 vehicle

The loading status of a vehicle	a, mm	b, mm	A, mm
L1 - Unloaded	962	1646	2608
L2 - Loaded (100 kg in the trunk)	1103.38	1504.62	2608
L3 - Loaded (200 kg in the trunk)	1234.64	1373.36	2608

3. NUMERICAL MODELING

Evaluation of analytical parameters braking capability of the vehicle taken in this study for the particular situation of its use, aims, through the development of a model calculation numeric in the MathCAD, of the results to be obtained with regard to parameter variations braking capability of the vehicle according to the pressure of the tires, loading on the axles, the nature and the condition of the rolling surface, tire type and the type of the braking system.

A driver directly influence the behavior and the movement of the vehicle or by braking, through the routing channels or by accelerating [12, 16, 17]. Common feature of all the processes of reaction is *the latency period* which takes from the time of the appearance of the need of braking up to the time at which the driver initiates a useful movement, in order to start the process of braking.

Assessment and comparison of the braking capability of a vehicle is carried out using the maximum deceleration relative or absolute terms, of the duration of braking and the minimum braking in the function of the velocity of the [12, 16, 17].

The space S_f necessary full braking of the vehicle is given by the relations [2, 12-14]:

$$S_f = S_{\hat{i}i} + S_{fmin}\text{, in m,} \tag{2}$$

where: S_{ii} represents the routing in the framework of the involuntary delays in m; S_{fmin} - the minimum amount of braking, in m.

The S_{ii} is given by the relations [2, 12-14]:

$$S_{\hat{i}i} = \frac{v}{3.6} \cdot t_{\hat{i}i}, \tag{3}$$

where: v represents velocity of the vehicle, in km/h; $t_{\hat{i}i}$ - the duration of the involuntary delays, which is the length of time elapsed from the moment in which the driver perceives the appearance of danger, up to the time at which the vehicle braking is constant.

Having regard to the anticipation of the situation of the triggering of the braking action within the framework of the duration of the perception-feedback of the driver is only takes into account the duration of the mechanical delays which relate to the length of time required for lifting the foot on the accelerator pedal, putting a foot on the brake pedal, the consumption of the free movement of the brake pedal, which has values of 0.1...0.2 s for the brakes with mechanical and hydraulic lines. The elapsed time since the beginning of the braking process and up to wheel lock (achievement of the effectiveness of the maximum braking) has values between 0.15...0.2 s for mechanical brakes or hydraulic [12-15].

To simulate the effect of the ABS system on the braking process, is used the relations [6, 11, 12, 16, 17]:

$$\varphi_{ABS} = \varphi + f, \tag{4}$$

where: φ is the grip coefficient; f - the coefficient of rolling resistance.

The minimum amount of S_{fmin} braking shall be determined in accordance with the relations [12]:

$$S_{f\,min} = \frac{k_e}{26 \cdot \varphi_{ABS} \cdot g} \cdot v^2, \tag{5}$$

where: k_e represents the coefficient of the effectiveness of the brakes (Table 2); g - gravitational acceleration in m/s^2; v - the velocity of the vehicle, in km/h.

In order to calculate the braking distances in the case of a rolling surfaces which are below a certain tilt angle α longitudinal, use the [14] relation (6) in the case of boarding and disembarking the relations (7), and in the case of the going down a slope. Both influence relations the grip coeficient and thus the stopping distance of the vehicle.

Table 2

The values of the effectiveness brakes coefficient, k_e

The vehicle type	**Without brake distribution unit**	**The brake with the distribution unit**
The vehicle	**Without load**	
	1.2	1.0
	With maximum load	
	1.2	1.0

$$\varphi_{UPHILL} = \varphi \cdot \cos\alpha + \sin\alpha, \tag{6}$$

$$\varphi_{DOWNHILL} = \varphi \cdot \cos\alpha - \sin\alpha. \tag{7}$$

The forces that acts on the drive wheels of the vehicles are limited to the grip between the tire and the path of the driving [4, 6, 8, 10, 11, 15]. The increase the value of the longitudinal force with both decreases the maximum value of the cross-sectional labor. For the calculation of the longitudinal and transversal forces that are transmitted between the tire and the rolling surface can be used the diagram in figure 3 [15].

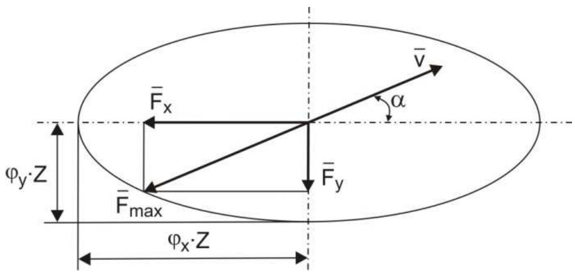


Fig. 3. The diagram of the forces between the tire and the rolling surface (tire traction ellipse). $\bar{v}$ - velocity; α - the angle which positions the velocity; $\bar{F}$ - reaction of the road on the wheel; $\bar{F}_x$, $\bar{F}_y$ - projections of the reaction in the longitudinal and transversal direction.

The maximum values of longitudinal/transversal reactions shall be calculated on the basis of the relationss [15]:

$$\begin{cases} F_{x_{max}} = \varphi_x \cdot Z \\ F_{y_{max}} = \varphi_y \cdot Z \end{cases}, \tag{8}$$

where: φ_x is the longitudinal grip coefficient (in general, the coefficient φ_x is abbreviated with φ);

φ_y - the lateral grip coefficient ($\varphi_y \cong 0.8 \cdot \varphi_x$); Z - vertical reaction of the road at the drive wheels.

Vertical reaction of the road Z is given by the relations [6, 11, 16, 17]:

$$Z = Z_1 + Z_2 , \tag{9}$$

where: Z_1 is the normal rection of the road to the wheels of the front axle; Z_2 - normal reaction of the road to the wheels of the rear final drive,

$$Z_1 = \frac{b + \varphi \cdot h_g}{A} \cdot G_a \cdot \cos\alpha , \tag{10}$$

$$Z_2 = \frac{a - \varphi \cdot h_g}{A} \cdot G_a \cdot \cos\alpha . \tag{11}$$

Because the tip of the vector $\bar{F}_{max}$ describes an ellipse (see Fig. 3), resulting in dependence on the value of the cross-sectional reaction F_y and the longitudinal F_x [3, 8, 15]:

$$F_y = \varphi_y \cdot Z \cdot \sqrt{1 - \frac{F_x^2}{(\varphi_x \cdot Z)^2}} , \tag{12}$$

Thus, by numerical modeling, may be some aspects related to the dynamic braking. The results obtained are with the interpretation of graphics card (Fig. 4...7) and are presented in the following.

The influence of the rolling surface on the braking distance (Fig. 4). The simulation of the case of the rolling surface was carried out by changing the grip coefficient φ, the latter having a value of 0.75 for the dry road and 0.55 for the wet road.

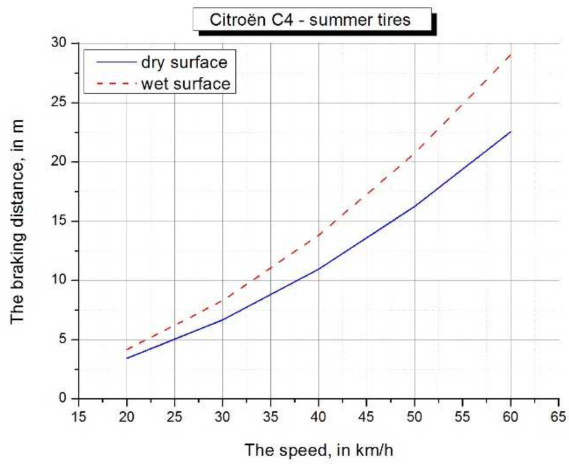


Fig. 4. The variation of the braking distance depending on the condition of the rolling surface, in the case of using the summer tires for unloaded Citroën C4 vehicle (result in numerical modeling).

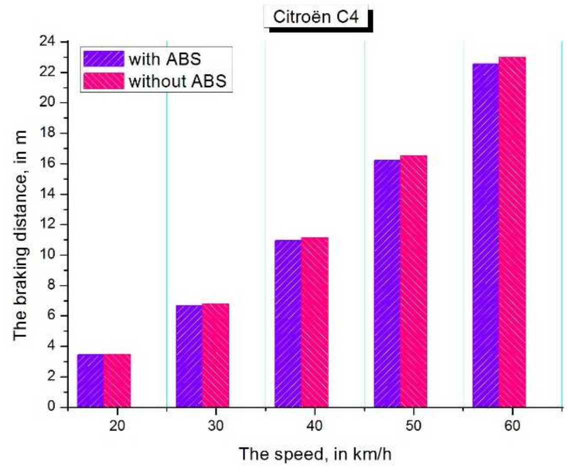


Fig. 5. The influence of the anti-locking system on the braking distance, in the case of using the summer tires for unloaded Citroën C4 vehicle, on the dry rolling surface (numerical model).

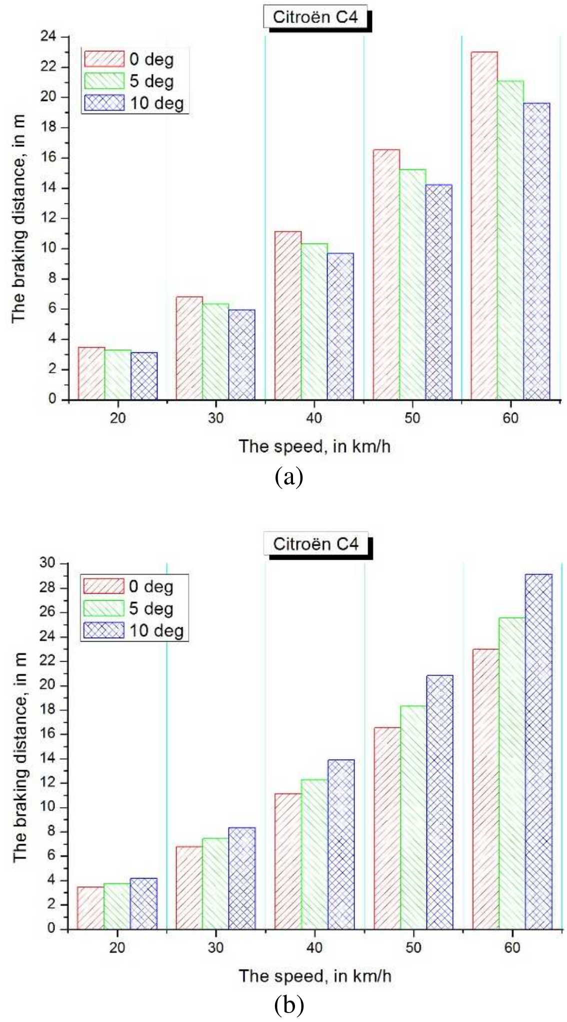
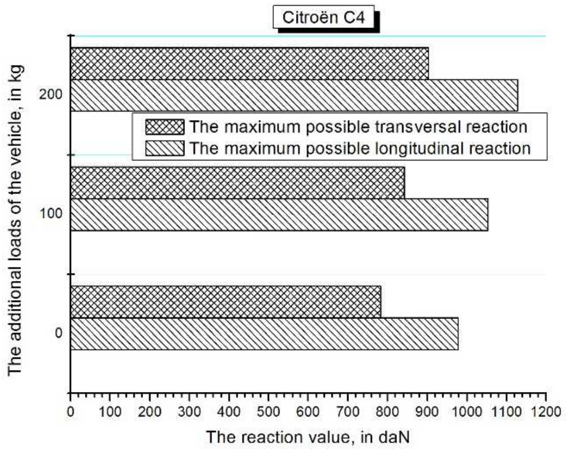
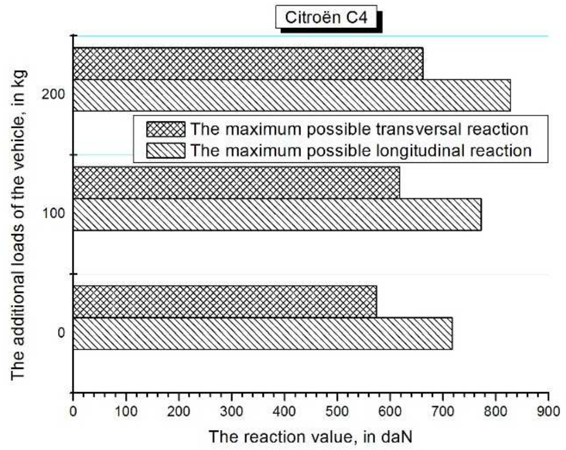


Fig. 6. The influence of the longitudinal inclination angle of the road on the braking distance, in the case of using the summer tires for the unloaded Citroën C4 vehicle, on the dry rolling surface. (a) in the case of uphill a ramp; (b) in the case of downhill a slope.



(a)



(b)

Fig. 7. The maximum variation of the longitudinal and transversal forces, depending on the additional load of the car, in the case of using the summer tires for Citroën C4. (a) for the dry rolling surface; (b) for the wet rolling surface.

The influence of the anti-locking system (ABS) on the braking distance (Fig. 5). The simulation of the effect of the ABS system on the brake qualities has been achieved through the use of a grip coefficient resulting from the relation (4).

The influence of the longitudinal inclination angle of the road on the braking distance. The results obtained, interpreted the graph shows the trends of reduction in the case of uphill (Fig. 6a) or increase in the case of lower (Fig. 6b) of distances necessary to complete the braking of the vehicle.

The variation in the longitudinal and transverse that are transmitted between the tire and the path of driving. The tire traction ellipse shall amend the parameters according to the nature and the condition of the road, travel speed and the loading status of the vehicle. The results of the captured in Figure 7 shows the variation of the longitudinal and transverse. In the case that one of the reactions has the value for the maximum possible, the other reaction forces should be zero. A lower value of reaction than the maximum possible, allows an increase of the other reaction, so that their resultant do not come out of the tire traction ellipse.

4. COMPUTERIZED SIMULATION

The computer simulations, using CarSim software, aimed at capturing the actual conditions of use of the vehicle taken under the study, in order to obtain comparative results as follows:

- the influence of the loading state of the vehicles on the braking distance for different travel speeds and different state of the rolling surface;
- the influence of the anti-locking system on the braking distance.

To use the simulation program CarSim involves browsing through some of the phases, such as [20]: setting the mode of simulation of the library available, configure the distinctive features of the vehicle and configuring the peculiarity of test procedure being predefined; running the program of simulation; presenting animated graphics and of the results. This allows the study of the dynamic behavior of motor vehicles of passengers, motor racing and of motor vehicles.

The first stage of preparation of the simulation consists in the choice of the type of vehicle and of what is necessary to be simulated. After the choice of the type of vehicle, it goes to setting the various parameters of such as: general dimensions of the vehicle, data about the system, data about the brake system, the type of suspension, tire size. Vehicles dimensions shall be determined on the technical sheet for them, and the coordinates of the center of gravity shall be calculated on the basis of each variant of additional charging (see Fig. 2 and Table 1).

The program for the CarSim simulation allows you to change the dimensions and of the total weight of the vehicles. Also in the settings for the vehicle, it allows setting the different properties of the ABS system and turning it off.

In addition to the parameters of the vehicle, the software allows you to choose the procedure required to be managed. In this case it is necessary to choose a procedure which enables the determination of the braking distance required to stop at different speeds of travel. The nature and the condition of the roadway may be taken into account by the values of the grip coefficient, the program allowing amendments to it.

Initially, it is necessary to choose the vehicle class whose simulation wants to be performed. Thus, for Citroën C4 to select the class C.

The computerized simulation tests of braking, with program CarSim 8.1, follows the determination of the distances in various conditions of use of the vehicle.

After carrying out simulations, were obtained data allowing the graphical interpretation of the results. So, for example, in Figures 8, 9 and 10 are surprised results for vehicle Citroën C4, with regard to:

- *the influence of the loading state of the vehicle on the braking distance for different velocities and different state of the rolling surface* (Fig. 8, 9);
- *the influence of the anti-locking system on the braking distance* (Fig. 10).

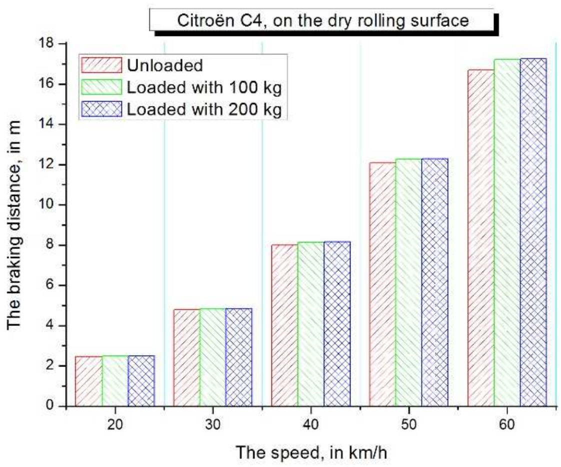


Fig. 8. The variation in the braking distance according to the vehicle load the vehicle for the *rolling surface of the dry matter*, in the case of the summer tires (result CarSim simulation).

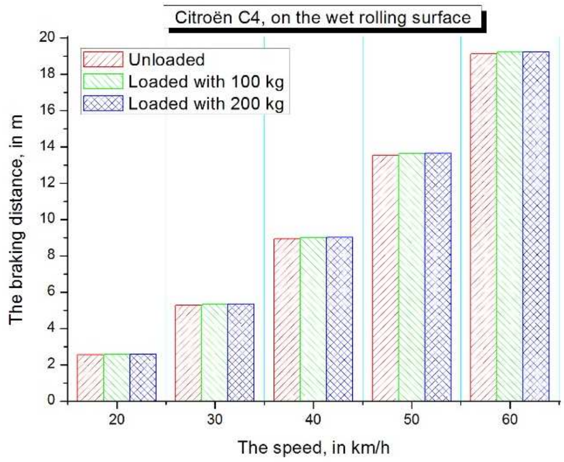


Fig. 9. The variation of the braking distance according to the vehicle load on the wet rolling surface, in the case of summer tires (CarSim simulation).

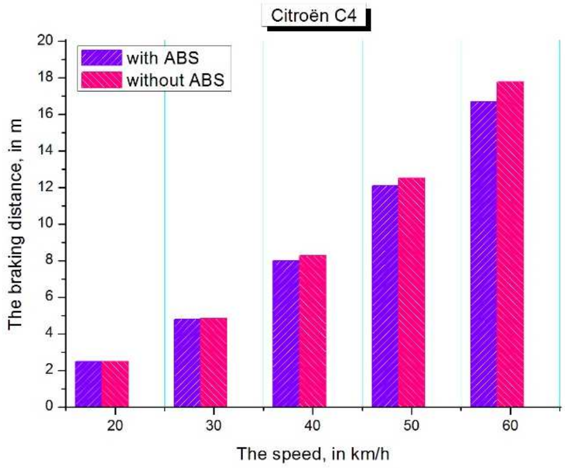


Fig. 10. The influence of the ABS system on the braking distance for the dry rolling surface, in the case of summer tires for unloaded Citroën C4 vehicle (CarSim simulation).

5. CONCLUSIONS

Based on the results obtained by both numerical model and computerized simulation, we can state the following:

- the mathematical model is an effective and inexpensive research method for the effect of the vehicle parameter variations on the braking process;
- the braking distance in the case of the wet road, characterized by a low grip coefficient ($\varphi = 0.4...0.6$), is higher than the braking distance on a dry rolling surface, which has a higher grip coefficient ($\varphi = 0.7...0.9$);

- the ABS system reduces the braking distance and increases its efficiency;
- in the case of going up a ramp under a longitudinal angle, the value of the angle is inversely proportional to the braking distance;
- in the case of going down a slope under a longitudinal angle, the value of the angle is proportional to the braking distance of the vehicle;
- the value of the longitudinal reaction and of the transversal one in the contact area between the tyre and the road, increases with the vehicle mass;
- in the case of driving on a straight line, the state of the road influences only the longitudinal reaction between the tyre and the road, the reaction being lower in the case of a decreased grip coefficient;
- specialised softwares allow effective and inexpensive simulations and the graphic interpretation of the result together with the operating system interface create a clearer image on the results obtained;
- computerised simulations allow the observation and recording of several dynamic parameters of the vehicles, at the same time allowing the conditions of the simulation:
  - ❑ changing the weather conditions;
  - ❑ changing the constructive parameters of the vehicles;
  - ❑ chosing the testing procedure;
  - ❑ the simultaneous interpretation of multiple results in a graphic mode;
  - ❑ exportind the data for further research;
  - ❑ creating an animated simulation model so that one can observe in real time the behaviour of the vehicles;
  - ❑ user friendly interface;
- the results obtained by computerized simulation show that:
  - ❑ any additional mass on the vehicle leads to the increase in the braking distance;
  - ❑ the braking distance increases proportionally with the additional mass of the vehicle, irrespective of the road condition;
  - ❑ a wet road determines a reduction of the grip coefficient and thus to a considerable increase on the braking distance;
  - ❑ the deactivation of the ABS system or braking when this one is missing leads to the increase in the braking distance and the loss of the longitudinal stability of the vehicle during the braking process;
  - ❑ the distribution of the braking force on each axle is done according to the load on each axle, thus reaching a greater spread of the braking force on the back axle, which influences negatively the vehicle's behavious during the braking process.

6. REFERENCES

[1] Abe, M., *Vehicle Handling Dynamics, Theory and Application.* Oxford, Butterworth-Heinemann, Published by Elsevier Ltd., 2009.

[2] Andreescu, C., *Dinamica autovehiculelor pe roţi, Vol. 1*. Bucureşti, Editura Politehnica Press, 2010.

[3] Brach Raymond, M. and Brach R. Matthew, *Vehicle Accident Analysis and Reconstruction Methods, Second Edition.* SAE International, 2011.

[4] Gaiginschi, R., *Reconstrucția şi expertiza accidentelor rutiere*. Bucureşti, Editura Tehnică, 2009.

[5] Khairnar, H.P., V.M. Phalle, and S.S. Mantha. *Estimation of automotive brake drum-shoe interface friction coefficient under varying conditions of longitudinal forces using Simulink*. Friction 3.3 (2015): 214-227.

[6] Macarie, T.N., *Automobile. Dinamica*. Piteşti, Editura Universităţii din Piteşti, 2003.

[7] Moustapha Doumiati; Olivier Sename; Luc Dugard; John-Jairo Martinez-Molina; Peter Gaspar; Zoltan Szabo, *Integrated vehicle dynamics control via coordination of active front steering and rear braking*, European Journal of Control, Volume 19,

Issue 2, March 2013, Pages 121-143, ISSN 0947-3580.
[8] Reza, N.J., *Vehicle Dynamics: Theory and Applications,* New York, United States of America, Editura Springers Science+Business Media, LLC, 2008.
[9] Shyrokau, Barys, et al. *Modelling and control of hysteresis-characterized brake processes*. Proc. of EuroBrake2012 Conference, 2012.
[10] Struble, Donald E., *Automotive Accident Reconstruction: Practices and Principles (Ground Vehicle Engineering Series)*. CRC Press, Taylor & Francis Group, LLC, 2014.
[11] Tabacu, Șt.; Tabacu, I.; Macarie, T.; Neagu, Elena, *Dinamica autovehiculelor. Îndrumar de proiectare*. Piteşti, Editura Universităţii din Piteşti, 2004.
[12] Todoruţ, A., *Bazele dinamicii autovehiculelor. Algoritmi de calcul, teste, aplicaţii.* Cluj-Napoca, Editura Sincron, 2005.
[13] Todoruţ, A., *Dinamica accidentelor de circulaţie.* Cluj-Napoca, Editura U.T.PRESS, 2008.
[14] Todoruţ, A.; Cordoș, N.; Barabás, I.; Bălcău, Monica, *Possibility of Evaluation the Pre-Collisions Speed and Space Crossing by Vehicle within Process of Braking*. Cluj-Napoca, Buletinul Ştiinţific al UTC-N, *Acta Technica Napocensis*, Series: *Applied Mathematics, Mechanics, and Engineering,* Vol. 57, Issue III, September, 2014, pg. 385-392, Editura U.T.PRESS, ISSN 1221-5872, http://www.atna-mam.utcluj.ro/index.php/Acta/article/view/394.
[15] Todoruţ, I.-A.; Barabás, I.; Burnete, N., *Siguranţa autovehiculelor şi securitatea în transporturi rutiere*. Cluj-Napoca, Editura U.T.PRESS, 2012.
[16] Untaru, M.; Poțîncu, Gh.; Stoicescu, A.; Pereş, Gh.; Tabacu, I., *Dinamica autovehiculelor pe roți*. București, Editura Didactică și Pedagogică, 1981.
[17] Untaru, M.; Câmpian, V.; Ionescu, E.; Pereş, Gh.; Ciolan, Gh.; Todor, I.; Filip, Natalia; Câmpian, O, *Dinamica autovehiculelor.* Braşov, Universitatea Transilvania din Braşov, Sectorul Reprografie U02, 1988.
[18] Vazquez Alvarez, I., et al. *Mathematical model for automobile's braking process considering a friction coefficient dependent of the longitudinal velocity*. Proceedings of the 15th WSEAS International Conference on Systems, 2011.
[19] ***, *Atestări inspectori ITP – Reglementările RNTR 1 (aprobate prin OMTCT nr. 2.133/2005, cu modificările și completările ulterioare),* http://www.rarom.ro/cs-uploads/RNTR%201.pdf.
[20] ***, *CARSIM, TRUCKSIM, BIKESIM AND SUSPENSIONSIM*. http://www.amet.it/software/vehicle-dynamics/carsim-trucksim-bikesim-and-suspensionsim/.

STUDII ASUPRA CALITĂȚILOR DE FRÂNARE ALE AUTOTURISMELOR PRIN MODELARE NUMERICĂ ȘI SIMULARE COMPUTERIZATĂ

Rezumat: În lucrare se urmărește evaluarea parametrilor care caracterizează procesul de frânare al autoturismelor, prin modelare numerică, în cazul diferitelor încărcări și a diferitelor condiții de drum, astfel încât conducătorul auto să conştientizeze acest lucru, adaptându-şi stilul de conducere la condiţiile de respective de trafic. Diferitele naturi și stări ale suprafeţei căii de rulare determină variaţia coeficientului de aderenţă, acesta influențând limita la care apare deraparea şi comportamentul întregului autoturism până la atingerea acestei limite. Toate aceste situaţii pot fi cauze ale producerii accidentelor dacă nu sunt corect evaluate de către conducătorul auto. Prin evaluarea comportamentului autoturismelor în fiecare din situațiile respective se realizează o pregătire suplimentară a conducătorului auto, care poate astfel anticipa limitele şi comportarea autoturismului, conducând în limite care să asigure siguranţa lui, a pasagerilor şi a celorlalţi participanţi la traficul rutier. Modelul de calcul analitic, dezvoltat în programul MathCad, ține seama de parametrii geometrici ai autoturismelor şi permite evaluarea analitică a parametrilor capacităţii de frânare a autoturismelor luate în studiu, pentru anumite situații de utilizare ale acestora, urmărindu-se obţinerea unor rezultate cu privire la variaţiile parametrilor capacităţii de frânare a autoturismelor în funcţie de presiunea din pneuri, încărcarea pe punţi, natura şi starea suprafeţei de rulare, tipul pneului şi tipul sistemului de frânare. Simulările computerizate s-au realizat cu ajutorul programului CarSim, urmărind studierea comportamentului autoturismelor în procesul de frânare, pentru diferite condiţii de utilizare, evidenţiindu-se astfel parametrii a căror variație determină modificarea parametrilor capacității de frânare. Rezultatele obținute sunt cu interpretare grafică, oferind posibilitatea unui studiu comparativ al acestora. Astfel, în situaţia în care nu se pot realiza determinări experimentale, precum în cazul autoturismelor aflate în stadiul de proiect, modelarea matematică, în funcţie de numărul gradelor de libertate atribuite modelului, poate furniza date care să caracterizeze calitățile de frânare ale autoturismelor.

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