CONTRIBUTIONS REGARDING THE STUDY OF THE BRAKING SYSTEM OF CARS

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Abstract

Braking process of a vehicle is complex, giving possibility to the driver to reduce car's speed or to stop it at big speed in a short distance. Using the diagrams registered for the different working conditions, defined accordingly with the experimental plan, there have been analyzed the values of deceleration, variation of speed and the covered space for each specified moment of braking. As result of the experimental researches, we have reached the conclusion that a good behavior at cars braking is registered when the diagrams of deceleration variation in relation with braking time have a symmetric shape.

Key words: vehicle stability, experimental braking process, ABS

Braking process of a vehicle is complex, being defined by factors leading to different effects from the point of view of impact, intensity and duration.

The braking system gives possibility to the driver to reduce car's speed or to stop it at big speed in a short distance.

Last generation cars are endowed with:
-Service brakes;
-Backup brakes;
-Handbrake;
-Auxiliary brake.

From the point of view of the vehicle's control and safety, the most important is the service braking system (the foot brake).

The longitudinal deceleration a_x is one of the main parameters of the braking system, which can be calculated with formula:

$$a_{xn} = \varphi_x \cdot g \quad (1)$$

where φ_x is the longitudinal coefficient of adherence of the tires with the running path and g – the gravitational acceleration ($g = 9.81\ m/s^2$).

The Directive of EU 71/320 (Council Directive 71/320/EEC, 1971) shows that this criterion has to satisfy the following condition:

$$a_{xn} \geq [0.1 + 0.85\ (\varphi_{xmax} - 0.2)].g \quad (2)$$

In the specialty literature, the given value for the adherence of the tires with the running path on a dry asphalt is $\varphi_x = 0.8$.

Introducing this value, which applies only to the vehicles and tires produced until 1980, in relations (1) and (2), there results the deceleration of a vehicle in good technical conditions, at braking on a dry asphalt

$$a_x = 6.0 – 7.85\ [m/s^2]$$

In the situation of actual cars, the maximum coefficient of adherence has the value $\varphi_x = 1– 1.2$ (Mitunevicius V., 1999) , if braking takes place on a running path with dry asphalt, situation when the deceleration of old cars with tires produced at the present moment can reach values in the range $7.35\div 9.3\ [m/s^2]$.

The modern cars are endowed with systems which prevent wheels blocking (ABS) and the real braking distance is quite close to the calculated value obtained with the maximum values of the coefficient of adherence. In this situation, the deceleration can be close to $g = 9.8\ [m/s^2]$.

1. ANTI-BLOCKING SYSTEMS (ABS)

Anti-blocking System is used at cars for avoiding the blocking of wheels during braking, for providing the stability of the vehicle and an optimal deceleration.

Anti-blocking of wheels is realized by adapting the braking force at each wheel, function of the wheel's adherence to the running path.

The advantages of a system (Neculaiasa V., 1996) assure keeping the vehicle under control, although the braking and the side forces are increasing, on a minimum braking distance with a reduced wear of tires.

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Some of the conditions to be accomplished by an ABS are following presented:
1. ABS must function on all the range of speeds;
2. ABS must correspond to the conditions of adherence with the running path;
3. To assure the steering of vehicle at slippages appearance;
4. To recognize aquaplaning and to respond to it;
5. To rapidly and automately correlate the hysteresis of tires at specific conditions;
6. The option of engine brake to be possible;
7. If an error at the ABS functions occurs, during braking, the braking system must function normally on classical principles.

The functioning principle of the anti-blocking system is based on rapid braking without wheels blocking, by applying short and rapid actions having as objective the delay of wheels blocking. This process is realized by the action upon the pressure of brake fluid from the brake installation, regulated to avoid the wheel blocking regardless the adherence to the running path.

In *figure 1* (GillespieT. D., 1992) there is presented the diagram of variation for the speed of a vehicle with ABS in relation with the braking time, for the four wheels of the car.

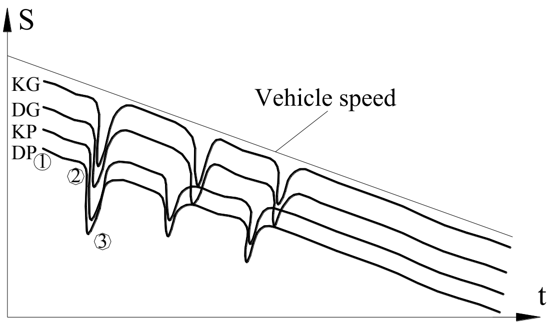

Figure 1 **Variation of speed in relation to the breaking time.**

When the brake pedal is acted, the value of wheels rotational speed is decreasing due to a true value depending to the vehicle's speed (pt.1 from *figure 1*). When the force which the brake is pressed with is bigger or the running path is slippery, the rotational speed of wheels significantly reduces (pt.2). In pt.3, ABS is activated and releases the brakes. When the rotational speed of wheels increases again, the brakes are once again activated, the process being repeated until the vehicle is brought to the desired speed.

1.1. Braking of vehicles without wheels blocking

If the car is not endowed with a regulator of the braking force of the ABS, the total braking force is differently distributed between the vehicle's bridges, from which reason the wheels of the front bridge and those of the rear bridge are not simultaneously blocked.

In the situation that the wheels have a good adherence to the surface of the running path, the rear wheels are first blocked, context in which the vehicle may lose transversal stability and if the front wheels are blocked, the control of the advancing direction can be lost.

A good behavior during braking is met when the motion of the car is continued in straight line at brake action, even for great speeds, condition imposed accordingly to the Directive of EU 71/320. So, in the moment when the emergency brake is acted, the motion of the car must continue in straight line, it means a bigger relative braking force upon the front wheels must be provided, in comparison with the force acting on the rear wheels.

The coefficient of distribution of the braking force (Illarionov, V. A., 1997) represents the ratio of the braking force acting on the front wheels, to the total braking force, acting on all the wheels.

$$\beta_{T} = P_{ST1} / (P_{ST1} + P_{ST2}) \quad (3)$$

P_{ST1} and P_{ST2} – represent the braking forces upon the front wheels and respectively upon the rear ones and they depend on structure of the brake system. This coefficient (β_T) can be calculated for any type of vehicle [5], accordingly to the known parameters of the brake system.

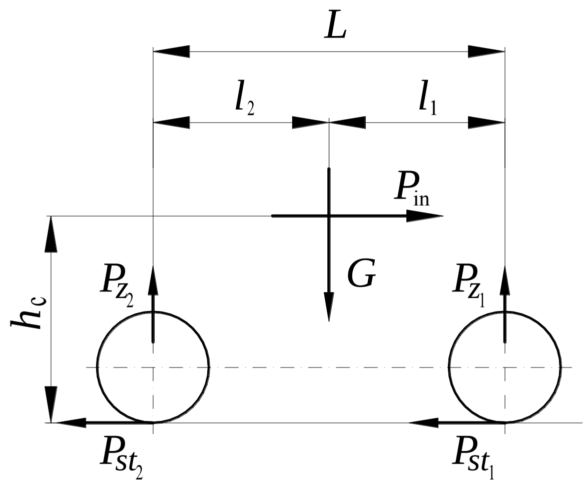

Figure 2 **Scheme of forces in the process of braking without wheelss blocking.**

In the situation of neglecting the loss of energy, for overcoming the resistance forces, the maximum of the deceleration for a vehicle at the limit of rear wheels blocking will be:

$$a_x = \frac{l_1 \cdot \varphi_x \cdot g}{L \cdot (1-\beta_T) + h_c \cdot \varphi_x} \quad (4)$$

Where: $l_1 =$ the distance in longitudinal direction, between the mass center of the vehicle and the front wheel, L represents the distance between wheels (the wheelbase) and h_c is the height of the mass center.

The maximum deceleration of a vehicle at the limit of front wheels blocking is:

$$a_x = \frac{l_2 \cdot \varphi_x \cdot g}{L \cdot \beta_T - h_c \cdot \varphi_x} \quad (5)$$

Where: l_2 = the distance between the rear wheel and the car's mass center.

The optimum coefficient of adherence φ_{opt} , will be given by relation:

$$\varphi_{opt} = (L \cdot \beta_T - l_2)/ h_c \quad (6)$$

In the conditions when the correct value of the coefficient of adherence exceeds φ_{opt}, the rear wheels will be firstly blocked by braking and relation (4) allows calculation of deceleration. In the situation when the value of the coefficient of adherence is smaller than the optimum value φ_{opt}, the front wheels will be the first blocked when the vehicle braking and the expression (5) will be used for calculate the deceleration.

When φ_{opt} has a value close to zero or is negative, only the rear wheels will be blocked in any situation of motion.

In the situation of a vehicle with unblocked wheels, the braking distance is calculated with formula:

$$S_0 = (t_1 + t_2 + 0.5 \cdot t_3) \cdot v_0 + v_0^2 /2a_x \quad (7)$$

In the situation when the initial speed of the vehicle (v_0) is not known, the braking distance of a vehicle with unblocked wheels (unlike the case of blocked wheels, when the slip length can be measured) can be determined with certain errors and this circumstance can influence the correctness of the obtained results.

In the situation of emergency braking, the braking forces acting on the vehicles' wheels should not exceed the forces of adherence of the tires at the running path, the calculated value of the deceleration of a vehicle with blocked wheels will be smaller and the braking time and braking distance will be bigger, in comparison with the case when the coefficient of adherence is known.

1.2. Comparison of the braking processes for vehicles with ABS and without ABS

From the study of vehicles' theory, the deceleration of a vehicle in good technical conditions without ABS reaches the top, fig.3, just at the beginning of the braking process and then some decreasings are happening, due to the fact that the top of deceleration is reached before blocking the vehicle's wheels.

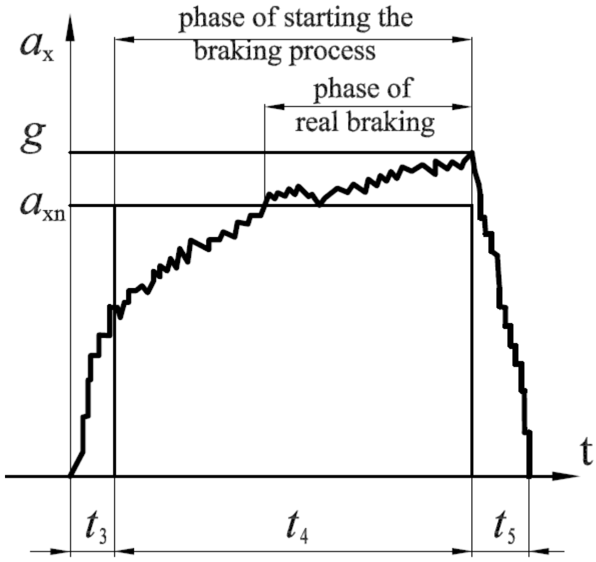

Figure 3 **Diagram of braking with ABS-phase of starting the braking process.**

After the wheels blocking, a decrease of the deceleration takes place, because braking of a blocked wheel is less efficient [6].

Maximum of deceleration lasts more during the braking of a vehicle without ABS at a lower speed; at a bigger speed, when the braking time is greater, the top of deceleration lasts less. This fact explains the decrease of speed for vehicles without ABS when a certain displacement speed is reached.

In fig.4 the diagram of variation of deceleration in relation with time is presented, during the period of speed variation of vehicle without ABS.

In specific road conditions, the value of the vehicle's deceleration may have a bigger correctness, which imposes an experimental research.

The deceleration of a vehicle on a running path can be measured using a special device (decelerometer) or can be calculated with relation (Sokolovsku E., 2004), if the initial speed v_0 and the braking distance are known.

$$a_{xn} = \frac{V_0^2}{26 \cdot S_4 + 3.6 \cdot V_0 \cdot t_3} \quad (8)$$

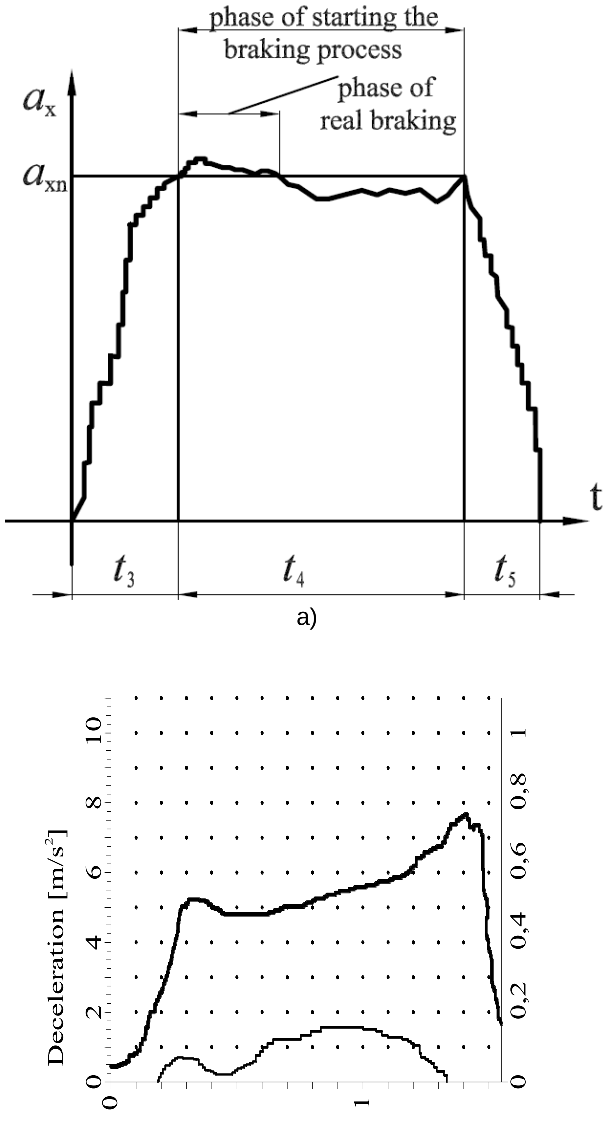

Figure 4 **Diagram of braking without ABS.**
a) phase of starting the braking process.
b) phase of real braking

2. EXPERIMENTAL RESEARCH UPON VEHICLE'S BRAKE

From those above presented, the necessity of developing some experimental researches upon the process of cars' braking has resulted. For experiments, two Daewoo cars in good technical shape and with the following characteristics have been used:

1) for vehicle without ABS

a) Vehicle category M 1;
b) Wheelbase of the vehicle, at dynamic test: 2360 mm;
c) Mass: nominal: 1050 kg, maximum: 1550 kg;
d) Maximum speed: 190 km/h;
e) Tires dimensions: 185/65 R 15;
f) Service brake with two independent circuits ;
1. Brake type : front: disk and rear : drum ;
g) Brake with double circuit;
h) Without ABS;
i) Mass of vehicle to be loaded:
-Test I: 1103 kg (667 kg + 436 kg)
-Test II: 1558 kg (798 kg + 760 kg)

2) for vehicle with ABS

a)Vehicle category M 1;
b) Wheelbase of the vehicle, at dynamic test: 2360 mm;
c) Mass: nominal: 1050 kg and maximum: 1600 kg;
d) Maximum speed : 190 km/h;
e) Tires dimensions: 185/65 R 15;
f) Service brake with two independent circuits ,in X;
g) Mark and type of brake lining: front: ferrodo 182 ; rear : DOW 8273 ;
h) Brake with double circuit;
i) Brake type : front: disk and rear: drum ;
j) Vehicle endowed with ABS;

The experiments have been done in the testing ground of Daewoo Craiova cars factory, on different running paths with surfaces covered with: asphalt dry - wet, gook, glaze, snow, car empty – loaded, engine clutched – declutched, and also in normal conditions of circulation on national roads in Botosani County, with the Testing Laboratory owned by SC ROMTURINGIA.

In the experiments, a device for measuring vehicles' deceleration (decelerometer) type MAHA VZN 100 was used. The device is appropriate for such measurements both for vehicles with hydraulic and pneumatic brake system and for those with ABS, as in fig.5.

The device is compound of: control board, for data displaying and registering; transducer wheel with its fixing support; flexible drive cable and dynamometric pedal (specific for braking tests).

The transducer wheel transmits rotational motion by the flexible cable to the control board, for displaying and registering, where the displacement speed can be read at any moment. In the registering apparatus, a time base is embedded, which electrical signals, at a period of one second, are marked on the registering paper, moving by rolling on the internal drums, with a speed proportional with the speed the wheel is running on the ground.

The used device measures the process parameters and draws the corresponding diagrams for speed, deceleration and the covered space, function of the type of braking.

The conformity of the measuring device VZN 100 with the standards stipulated for the device's checking is certified by the German Association for Technical Inspection (TUV) [5].

This device is also used by the Lithuanian centers for technical inspection for establishing the efficiency of the brake system, basing on the maximum deceleration.

Using the diagrams registered for the different working conditions, defined accordingly with the experimental plan, there have been analyzed the values of deceleration, variation of speed and the covered space for each specified moment of braking.

As result of the experimental researches, we have reached the conclusion that a good behavior at cars braking is registered when the diagrams of deceleration variation in relation with braking time have a symmetric shape.

Based on the found parameters of vehicle's motion, we can provide the variation of the maximum values of deceleration for specific situations.

CONCLUSIONS

Based on the bibliographical researches in the considered technical field and on the experimental researches, certain conclusions of undoubted importance can be presented:

I. In the developed experiments, the deceleration established for vehicles with ABS have varied from 8.05 m/s^2 (at the speed of 40 km/h) up to 8.45 m/s^2 (at the speed of 80 km/h), and often the maximum values have been close to 9 m/s^2.

For vehicles without ABS, the deceleration have varied from 7.05 m/s^2 (at speed of 40 km/h) up to 6.87 m/s^2 (at speed of 60 km/h) and up to 6.65 m/s^2 at a speed of 80 km/h. When v_0 increases, the difference of deceleration or vehicles with and without ABS increases with 11.1%, 18% and respectively 24%.

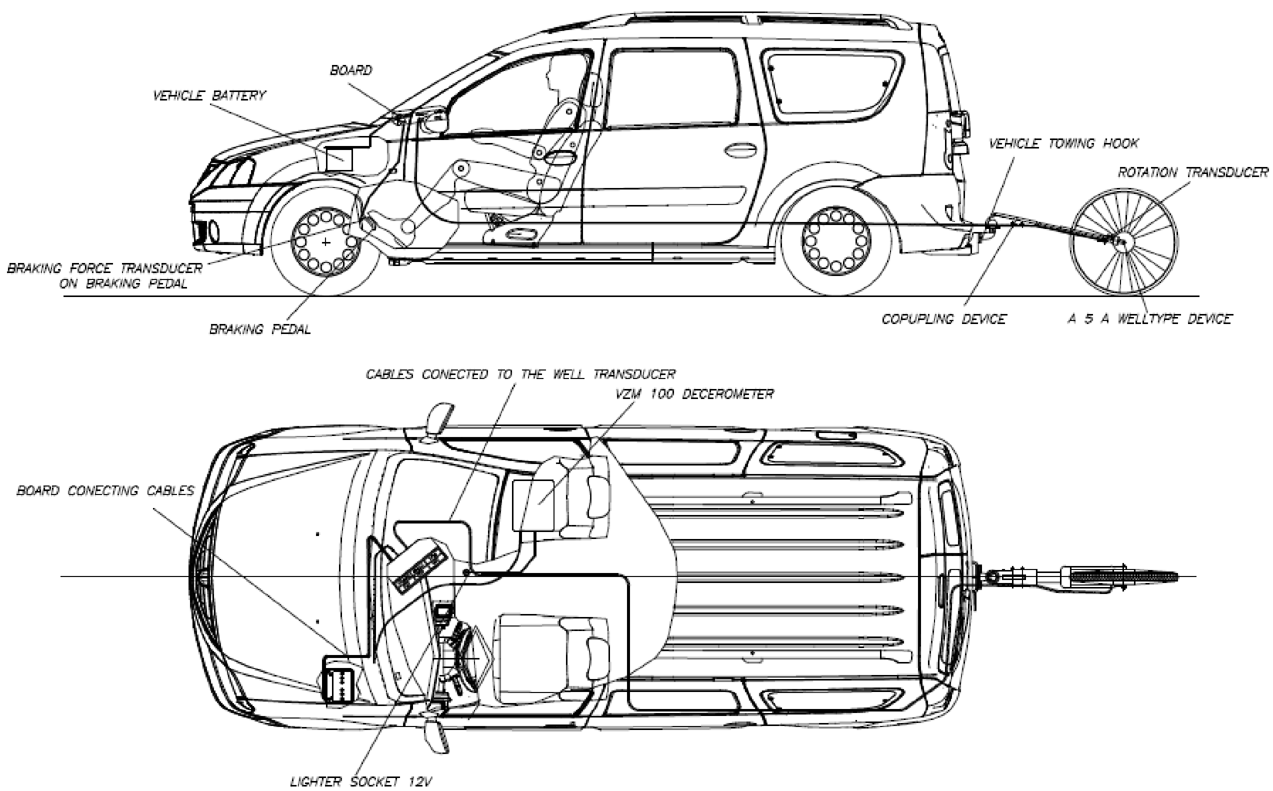

Figura 5 **Principle scheme of a car endowed with the 5th whell.**

II. There was calculated that the average of braking distance for a vehicle with ABS is smaller with 4.25% in comparison with those for a vehicle without ABS.

If the initial motion speed is 40 km/h, and if v_0 = 80 km/h, approximately the deceleration is modifying up to 15.59%;

If v_0 = 60 km/h, the braking distance for vehicles with ABS was of 20.80 m, and for vehicles without ABS it was of 22.42 m, the difference being of approximately 7.35%.

III. The value of the braking distance can be calculated based on the braking process parameters, such as: braking time t_3, the value of deceleration a_{xn} and the initial speed v_0.

There is proposed the use of the values of the parameters determined within the experimental research for the examination of situations specific for traffic accidents, for a more correct defining of the methods for calculating the braking parameters for cars with or without ABS.

IV. As a result of research accomplishing, there has been noticed that the used cars are corresponding and respect the stipulations of the Regulations of braking R-13ECE – ONU. That is why the regulations of EU impose for all the cars built since 2011 the obligation of endowment with ABS.

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