DETERMINE THE PARAMETERS OF THE BRAKING CAPACITY OF THE SPECIAL VEHICLES BRAKING SYSTEMS

Alin-Marian PUNCIOIU, Marian TRUȚĂ

Military Technical Academy, Bucharest

Abstract: *This paper shows parameters that characterize braking motors vehicles, the deceleration, the braking space and the braking time, and the method of their determination. The technical condition of the assembly of the braking system components is a determining factor that can influence driving safely and affects, to an extent decisive, the addition of value to performance speed and acceleration of the vehicle. The importance of the characteristics of the braking system is derived from the active handling mode of the vehicle.*

Keywords: *braking system, deceleration, braking space, braking time.*

1. INTRODUCTION

Special vehicles on wheels appeared as a necessity to bring them into objective compliance to fight in accordance with the conditions to complete the portions of the unarranged fields, with high speed, use of a vehicle for military purposes revolutionizing land forces mobility.

For the proper conduct of the special vehicles mission in rough terrain, we are talking about, on one hand, the importance of the possibility of immobilization and retaining position and, on the other hand, during the braking process, the importance movement stability and reversibility or reversibility, to an encounter with an obstacle.

In view of the permanent trends of producers of motor vehicles to increase the dynamic quality for their models of machines, as well as congestion and increased unwanted events of the traffic it can be noted the value of braking system, as a critical component that can influence the increasing of the value of indices of operation of power – driven vehicles.

The importance of the characteristics of the braking system is derived from the handling active mode of the vehicle and offers the possibility of change in velocity and acceleration, during operation.

The kinetic energy gained by the motor vehicle, for the maintenance of the braking system operated shall be converted, on the one hand, to calorific energy by friction - energy which is then dissipated into the environment, and on the other hand are consumed in order to overcome rolling resistance and air which are always opposing the movement of the vehicle.

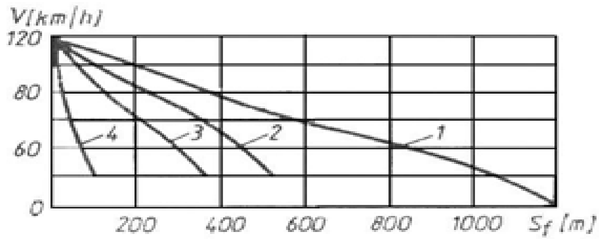

Fig.1 The dependence of the vehicle braking space towards the braking process. – after Frățilă Gh. (1986)

Figure 1 shows space dependence of the braking function of the car’s braking process. In case no car brakes are used, the amount of space off (curve 1) is conditional on rolling resistance and air resistance, as well as the mechanical losses in the transmission. As a result, the forces have little effect especially at moderate speeds.

If the engine does not disengage, running resistances increase (on account drag torque of the engine), and the space travelled up to the halt of the vehicle shall be greatly reduced (curve 2).

The braking effect increases even more, if the engine is forced to operate as a compressor, by blocking the exhaust pipe before the muffler (curve 3). If the vehicle's brakes are used, the amount of space to a stop shall be reduced very much (curve 4).

The braking devices must meet a number of conditions constructive and functional for the purpose of ensuring the braking capabilities of the vehicle as well as to be able to implement the performance value speed and acceleration safely.

2. BRAKING CAPABILITY PARAMETERS

The parameters that characterize vehicles braking systems are deceleration, the braking space and the braking time. Layout forces and moments acting on the car in the braking process [3], in the general case, are shown in figure 2.

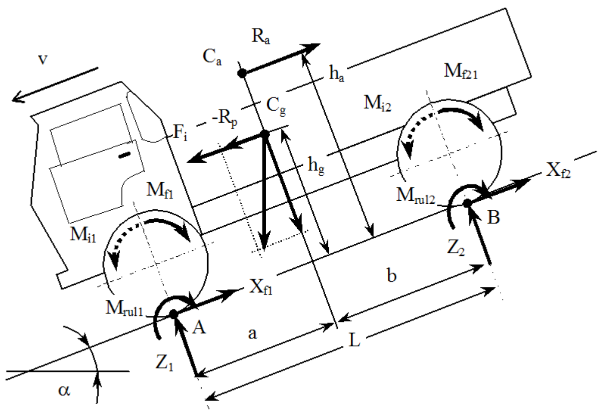

Fig. 2 Layout forces and moments acting on a power – driven vehicle braked – after Marinescu M. (2000).

C_g- the center of gravity; C_a- the center of pressure; R_a- air resistance; ($-R_p$)-„grade resistance" on a slope; F_i- inertia force; G_a- vehicle weight; h_g- the height of the center of gravity; h_a- the height of the center of pressure; a, b- distances front/rear from the center of gravity to the support points of the wheels, and wheelbase; L-wheelbase; α- gradient angle; $M_{i1,2}$- moments of inertia of the wheels; $M_{f1,2}$- moments of braking applied wheels; $M_{rul1,2}$- moments of rolling resistance; $Z_{1,2}$- the roadway reactions; $X_{f1,2}$- tangential braking reactions.

In fig 2, air resistance has the known expression: $R_a = kAv^2$, in which A represents the front surface area, k is the coefficient of resistance of the air, and v is the speed [m/s].

Also, the inertia force is given by $F_i = \frac{G_a}{g}\frac{\mathrm{d}v}{\mathrm{d}t}$, where $\frac{\mathrm{d}v}{\mathrm{d}t}$ is the deceleration and grade resistance $R_p = G_a \sin\alpha$, is in fact, a driving force, because the vehicle goes down on a slope. Taking into consideration the forces of inertia, it is possible to apply the principle of d' Alembert. Thus, from the balance in the direction of movement, after the replacements, results:

$$\frac{G_a}{g}\frac{\mathrm{d}v}{\mathrm{d}t} = X_{f1} + X_{f2} \mp G_a \sin\alpha + kAv^2$$

2.1 Determination of deceleration. The easiest way to determine it is the experimental way.

In the case of four – wheel braking, maximum deceleration is obtained when all wheels are transmitted simultaneously at adhesion limit, in which case the tangential reactions expressions will be: $X_{f1} = \varphi Z_{1\varphi}$, and $X_{f2} = \varphi Z_{2\varphi}$, where the two normal reactions are limited of adhesion.

From the equation the projection of forces normal to the direction of movement (fig.2), the following relationship shall be obtained:

$$\left(X_{f1} + X_{f2}\right)_{\max} = \varphi\left(Z_{1\varphi} + Z_{2\varphi}\right) = \varphi G_a \cos\alpha$$

providing maximum deceleration value in the general case:

$$\left.\frac{\mathrm{d}v}{\mathrm{d}t}\right|_{\max} = g\left(\varphi\cos\alpha \mp \sin\alpha + \frac{kAv^2}{G_a}\right)[\mathrm{m/s^2}]$$

or neglecting air resistance movement on level ground:

$$\left.\frac{\mathrm{d}v}{\mathrm{d}t}\right|_{\max} = g\varphi\,[\mathrm{m/s^2}]$$

In the case of the wheel braking only front axle, maximum deceleration is obtained for $X_{f1} = \varphi Z_{1\varphi}$, and the disappointed tangential to rear wheels will be $X_{f2} = \not{f}Z_2 - \frac{2I_{r2}}{r_r^2}\frac{\mathrm{d}v}{\mathrm{d}t}$.

In accordance with motor vehicle dynamics, exclusive use of brake front axle wheel, normal reactions dynamic will be provided by:

$$Z_{1\varphi} = \frac{\frac{b}{L}}{1-\varphi\frac{h_g}{L}}G_a\cos\alpha\text{, and}$$

$$Z_2 = \frac{\frac{a}{L}-\varphi\frac{h_g}{L}}{1-\varphi\frac{h_g}{L}}G_a\cos\alpha,$$

with that if it will calculate maximum deceleration, with the provision that the term

$$\frac{g}{G_a}\frac{2I_{r2}}{r_r^2} < 1,$$

and rolling resistance is negligible in relation to the other forces will be obtained for maximum deceleration in this situation of operation:

$$\left.\frac{\mathrm{d}v}{\mathrm{d}t}\right|_{\max} = g\left(\varphi\frac{\frac{b}{L}}{1-\varphi\frac{h_g}{L}}\cos\alpha \mp \sin\alpha + \frac{kAv^2}{G_a}\right)$$

or neglecting air resistance, when traveling on level ground:

$$\left.\frac{\mathrm{d}v}{\mathrm{d}t}\right|_{\max} = g\varphi\frac{\frac{b}{L}}{1-\varphi\frac{h_g}{L}}[\mathrm{m/s^2}]$$

In the case of braking only on the rear axle wheels, maximum deceleration is obtained for

$X_{f2} = \varphi Z_{2\varphi}$, and $X_{f1} = \not{f}Z_1 - \frac{2I_{r1}}{r_r^2}\frac{\mathrm{d}v}{\mathrm{d}t}$,

in which case normal reactions expressions are:

$$Z_1 = \frac{\frac{b}{L}+\varphi\frac{h_g}{L}}{1+\varphi\frac{h_g}{L}}G_a\cos\alpha\text{, and}$$

$$Z_{2\varphi} = \frac{\frac{a}{L}}{1+\varphi\frac{h_g}{L}}G_a\cos\alpha.$$

Neglecting also, $\frac{g}{G_a}\frac{2I_{r2}}{r_r^2} < 1$,

air resistance and rolling resistance is obtained when traveling on a slope:

$$\left.\frac{\mathrm{d}v}{\mathrm{d}t}\right|_{\max} = g\left(\varphi\frac{\frac{a}{L}}{1+\varphi\frac{h_g}{L}}\cos\alpha \mp \sin\alpha\right)$$

or on the roar surface:

$$\left.\frac{\mathrm{d}v}{\mathrm{d}t}\right|_{\max} = g\varphi\frac{\frac{a}{L}}{1+\varphi\frac{h_g}{L}}[\mathrm{m/s^2}]$$

It should be noted that in all the variants previously been treated decelerations are obtained from maximum braking without locking the wheels, because after locking, the value of adhesion and therefore the size of the braking force developed are to be reduced by reducing coefficient of adhesion due to slipping.

If braking with all wheels (like in the case of normal operation) hypothesis allowed requires that the braking force to be distributed among the axels at the same ratio as well as axel loads.

As the hypothesis said they suppose braking at adhesion limit it doesn't matter if braking will be done with or without engine disconnected from transmission or it is used in conjunction any retarder.

2.2 Determination of the braking area. The braking space determines directly the braking qualities of a motor vehicle, being in close liaison with road safety.

For determining the relationship of the calculation of the braking space we start from the definition of deceleration, which may be written in the form $\frac{\mathrm{d}v}{\mathrm{d}t} = \frac{\mathrm{d}v}{\mathrm{d}S_f} \cdot \frac{\mathrm{d}S_f}{\mathrm{d}t} = \frac{\mathrm{d}v}{\mathrm{d}S_f} v$, from where it results the elementary braking space S_f.

Using previous relationship and considering that speed varies during braking from v_1 to v_2, the relationship for the calculation of the braking space is:

$$S_f = \frac{1}{g} \int_{v_2}^{v_1} \frac{v\mathrm{d}v}{\frac{X_{f1} + X_{f2}}{G_a} \mp \sin\alpha + \frac{kAv^2}{G_a}}$$

Making assumption that braking is done at adhesion limit on all of the wheels and considering the tangential braking reactions X_{f1} and X_{f2} are constant, at the same time neglecting air resistance, previous relationship becomes:

$$S_f = \frac{1}{g} \int_{v_2}^{v_1} \frac{v\mathrm{d}v}{\frac{X_{f1} + X_{f2}}{G_a} \mp \sin\alpha} = \frac{v_1^2 - v_2^2}{2g\left(\frac{X_{f1} + X_{f2}}{G_a} \mp \sin\alpha\right)}$$

and therefore minimum braking space becomes (for X_{f1} and X_{f2} with maximum values):

$$S_{f\,\min} = \frac{v_1^2 - v_2^2}{2g(\varphi\cos\alpha \mp \sin\alpha)}$$

and, in the case braking to a stop on a level road:

$$S_{f\,\min} = \frac{v_1^2}{26\, g\varphi},$$

from where it can be seen that the space of braking is in directly proportion to the square of the speed at which braking starts and inversely proportional to the value of the coefficient of adhesion.

2.3 Determination of the braking time. The braking time is of importance especially in the analysis of work processes of the braking device [1], and it is less used in appraising braking capability.

To establish relationships for the calculation of the braking time we start from the expressions of the braking vehicle movement equation or deceleration.

$$T_f = \frac{\delta}{3{,}6g} \int_{v2}^{v1} \frac{dv}{\gamma_f + \psi + \frac{v^2 kA}{13\, G_a}} \; [\mathrm{s}]$$

in case we consider $\gamma_t = const$ and we neglect air resistance:

$$T_{f\,\min p} = \frac{1}{3{,}6g} \frac{v_1 - v_2}{\varphi\cos\alpha \mp \sin\alpha} \; [\mathrm{s}]$$

and, in the case braking to a stop on a level road $T_{f\,\min p} = \frac{v_1}{3{,}6g\varphi}$

2.3 Vehicle braking diagram. Analysis of the braking process and determine the parameters of the braking capacity has been made on the assumption that the braking system of the motor vehicle shall enter into action instantly and develop maximum braking force to a certain value of the power of the pedal.

In fact, from the moment in which there is a need braking and to peak deceleration a certain period of time must pass, determined by driver and braking system response of the motor vehicle. This is highlighted in Fig. 3.

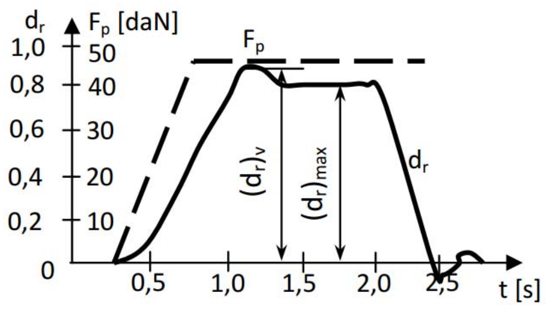

Fig. 3 – real chart of the braking of a vehicle – after Fratila Gh. (1986)

F_p- force of the pedal, d_r- the deceleration, d_{rv}- the peak value of deceleration, d_{rmax}- the maximum value of the deceleration.

CONCLUSIONS

Because of the significant role that the braking installation has to ensure the safety of movement, it is essential that it has a close to 100% reliability. To meet this requirement a series of constructive measures were taken, in order to permit vehicle braking effectiveness sufficient in the event of the appearance of damage in a section of the braking device or warn in time the driver about an eminent reduction in efficacy.

For road obligatory safety minimum values shall be described for braking efficiency expressed as maximum length of the space of braking and the minimum amount of deceleration, which are to be maintained for the exploitation of motor vehicles. Thus, the braking installations for motor vehicles must comply with the following conditions:

- must be capable of certain deceleration imposed, and braking is progressive, shock – free with maintaining stability of vehicle during braking, which shall, in particular, ensure the correct distribution of the braking effort to decks;
- not to require a higher effort from the driver, and braking shall be provided solely to driver's intervention; they must not be possible to engage concomitant of the brake pedal and accelerator pedal;
- conservation qualities of the braking vehicles in all working conditions encountered in service in all situations of use; to provide heat discharge which shall arise during braking;
- adjustment of the clearances to make themselves as less often and convenient or even in automatic mode; walking up and running quickly, and the braking force to act in both directions of movement of vehicle;
- braking should not be influenced by uneven road surface (due to the vertical movement of the wheel) and turning the steering wheel and have quiet operation;
- to allow motor vehicle immobilized on a slope in the case of a de facto ally of long direction;
- it must be designed, constructed and installed in such a way as to resist corrosion phenomena and aging to which they are exposed;
- not to allow oil and dirt to enter at the friction surfaces;
- to have a simple construction and a low cost.

ACKNOWLEDGMENT

This paper has been financially supported within the project entitled "Horizon 2020 -Doctoral and Postdoctoral Studies: Promoting the National Interest through Excellence, Competitiveness and Responsibility in the Field of Romanian Fundamental and Applied Scientific Research", contract number POSDRU/159/1.5/S/140106. This project is co-financed by European Social Fund through Sectoral Operational Programme for Human Resources Development 2007-2013. Investing in people!

BIBLIOGRAPHY

1. Frățilă, Gh., Mărculescu, Gh., *The braking systems of motor vehicles*. Bucharest: Technical Publishing House (1986).
2. Ghiulai, C., Vasiliu, Ch., *Motor vehicle dynamics*. Bucharest: Didactical and Pedagogical Publishing House (1975).
3. Marinescu, M., *Modern Solutions in Vehicle Manufacturing*. Military Technical Academy Publishing House (2002 - in Romanian).
4. Untaru, M., ş.a., *The calculation and construction of motor vehicles*. Bucharest: Didactical and Pedagogical Publishing House (1974).
5. Untaru, M., ş.a., *The dynamic of motor vehicles on wheels*. Bucharest: Didactical and Pedagogical Publishing House (1981).