CONSIDERATIONS ON THE BEHAVIOR OF THE BRAKING SYSTEM ON CARS TOWING TRAILERS

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ABSTRACT. Funcționarea corespunzătoare a sistemelor de frânare ale autoturismelor care trag remorci este o condiție esențială pentru siguranța circulației pe drumurile publice. În timpul deplasării remorcilor fără sistem de frânare, solicitările suplimentare care apar în timpul frânării sunt preluate de autoturismul tractor. În această lucrare sunt prezentate abordările referitoare la această problemă. care pot fi găsite în literatura de specialitate Lucrarea prezintă și câteva aspecte legislative cu referire la sistemele de frânare.

Cuvinte cheie: remorcare, frânare autoturisme, legislație rutieră.

ABSTRACT. The proper functioning of the braking systems of passenger cars towing trailers is an essential prerequisite for traffic safety on public roads. During the movement of trailers without a braking system the additional stresses occurring during braking are taken over by the towing passenger car. In this paper a presentation of the approaches that can be found in the speciality literature concerning this issue is presented. The paper also presents some legislative aspects with reference to braking systems.

Keywords: towing, braking cars, road legislation.

1. PROLEGOMENA

Regarding the braking systems of cars towing a trailer without a braking system, our own research has found that there is no research or study, let alone legislation or performance standards governing these issues.

A significant problem in trailer towing safety is the increase in braking distances due to the overall increase in overall assembly mass without a commensurate increase in braking effectiveness. [7][8].

Even if there were some specific standards for braking systems, there are many variables that influence the braking distance of trailer and car combinations.

The braking is achieved by generating a braking moment in the braking mechanisms of the wheels, which causes a braking force to be applied to the wheels in the direction of the vehicle's speed but in the opposite direction.

The braking system of motor vehicles is the main device that can ensure the safety of the vehicle and its load. The mass of the vehicle, load and passengers are the basic design data for the braking system. Being so important for road safety, they must be maintained in perfect working conditions [6].

The need for an efficient braking system has led to its continuous improvement, with research and development becoming increasingly complex with the advent of advanced data acquisition systems.

Today, braking mechanisms are electronically assisted by complex systems such as ABS, which ensures wheel contact with the road surface; Electronic Stability Control (ESP), which provides dynamic control of vehicle stability by detecting skidding; and other anti-skid systems [7][8].

The most crucial elements for ensuring safety and preventing accidents while operating a vehicle are the braking system and tires, in conjunction with the steering system.

The safety of the vehicle, and the benefit of its performance, is linked to how the braking system works.

2. LEGISLATIVE ASPECTS

Figure 1.3. shows the classification according to EU Regulation 2018/858 on type-approval and market surveillance of motor vehicles and their trailers. Road vehicles include cars, motorcycles, towed vehicles and road trains. This category does not include agricultural tractors [4].

The purpose of this classification is to define different categories of vehicle use.

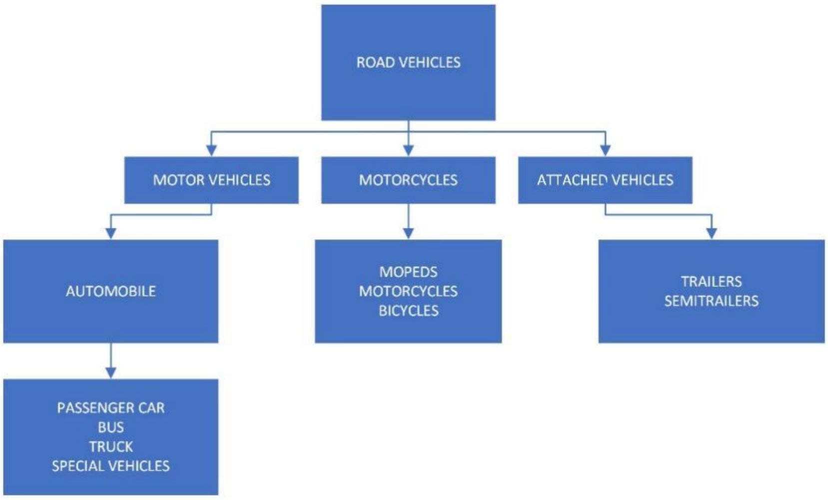

Fig. 2.1. Types of land vehicles according to EU Regulation 2018/858.

From a legislative point of view, UN-ECE Regulation No. 13 contains uniform requirements for the approval of vehicles of categories M, N and O with regard to braking systems.

Table 1.1. shows the legal braking performance of the braking systems of category M vehicles [9].

Table 1. **Test conditions of braking systems.**

Automotive		**Test speed [km/h]**	**Max. pedal force [daN]**	**Braking space calculation [m]**	**Average decel. [m/s²]**
Type	Cat.				
Cars	M_1	80	50	$S_f \leq 0{,}1v + \frac{v^2}{150}$	5,8

3. THEORETICAL ASPECTS OF BRAKING SYSTEMS

The assessment of an automobile's braking performance involves evaluating the braking distance, braking time, and braking acceleration.

Braking tests consist of the determination of one or more of the listed parameters for different characteristic states or modes of operation of the braking systems of an automobile.

Efficient braking is an important requirement for motor vehicles and can be considered in two ways:

– the achievement of traffic safety on public roads;

– to achieve better conditions for off-road driving by reducing the space and time required for braking.

A number of factors can influence vehicle braking. An effective braking system takes into account the factors shown in figure 2.2.

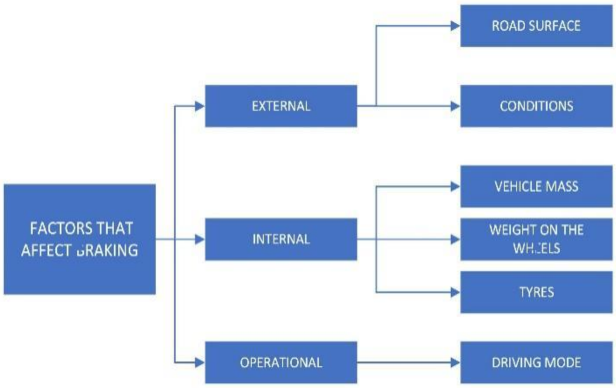

Fig. 3.1. The factors influencing vehicle braking.

The process of braking consists of two distinct stages.:

– the conventional initial response time, of duration t_R , where the vehicle continues to travel at the initial speed (v);

– the initial conventional braking time, of duration t_F, during which the vehicle's motion is uniformly slowed down with deceleration a_m, taken as constant.

Between the external parameters of the braking process: the braking space S_f [m], the braking time t_F [s], and the deceleration during braking a_m, there are the relations:

$$a_m = \frac{v_i^2}{2(v_i \cdot t_F - S_F)}, [m/s^2] \quad (3.1)$$

where: v_i is the initial vehicle speed in m/s.

The conventional initial response time:

$$t_R = \frac{2(S_F - v_i \cdot t_F)}{v_i}, [s] \quad (3.2)$$

The development of the braking system of a modern road vehicle is the result of technological advances in four distinct engineering fields. These are materials science and engineering, mechanical engineering, electronic engineering and software.

Continuous and precise control of braking system components using computers (ABS) have brought braking into the area of active vehicle safety. Since the late 1960s, when the first ABS systems appeared, the importance for road safety of maintaining steering control during braking or under high deceleration conditions has been demonstrated [3].

Braking systems can be classified according to the type of actuation: mechanical, pneumatic, hydraulic and combined (fig. 3.1). Other systems include regenerative braking systems [5].

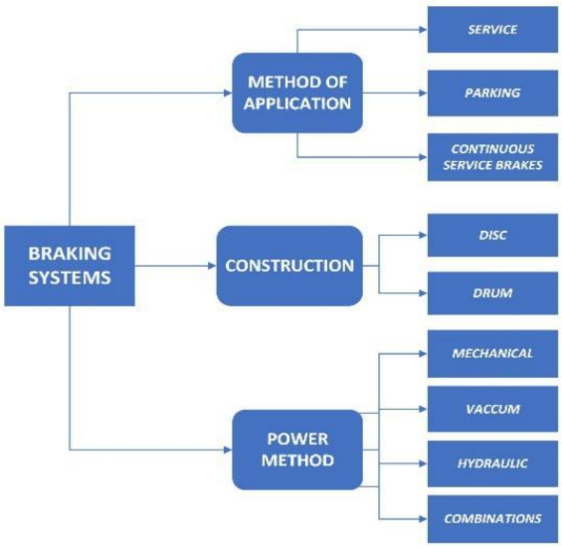

Fig. 3.2. The classification of braking systems.

Due to their simplicity of design, adaptability and reliability, most braking systems are hydraulically actuated. They can be disk and/or drum brakes [1].

Disc braking systems are widely used in the automotive industry due to their efficiency under different braking conditions and thermal advantages over drum braking systems.

Drum brakes are generally used on the rear axle of motor vehicles. They are constructed and implemented in the braking system because they are economical in design. Their disadvantage is that they are thermally limited.

4. THE DYNAMICS OF VEHICLES TOWING TRAILERS

The braking of a car towing a trailer is different from the situation when a car is driving without a trailer. If the vehicle is braked with an additional weight of 750 kg at the rear, obviously the braking results will be different. The literature shows that braking while towing a trailer is totally different from braking without a trailer. All the added mass of a trailer makes a vehicle slow down in a longer time [2].

Figure 2.4 displays a free-body diagram of the system of forces for a combination of vehicles and light trailers in dynamic equilibrium. The two parts of the combination are connected to the towing hitch, but are analyzed separately, as shown in Figures 2.5(a) and Figure 2.5(b). At the drawbar coupling, the following coupling forces are transferred between the vehicle and the trailer:

– vertically loaded towing hook N_4;

– horizontal towing force T_4.

Because the trailer is braked by the towing vehicle in this configuration, the drawbar will be in compression, so the horizontal tractive force will be negative on the vehicle and positive on the trailer.

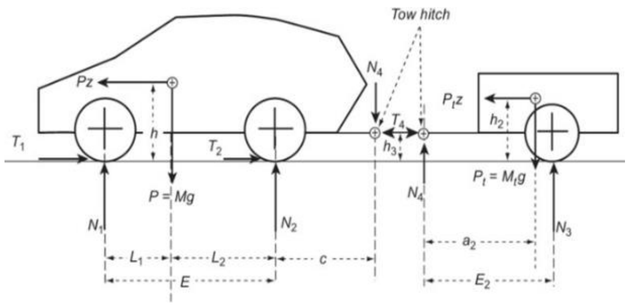

Fig. 4.1. Combined forces system for vehicles and light trailers under dynamic braking conditions. [3]

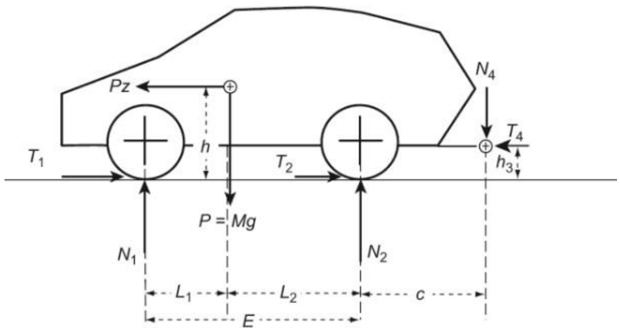

Fig. 4.2. Forces acting on the vehicle. [3]

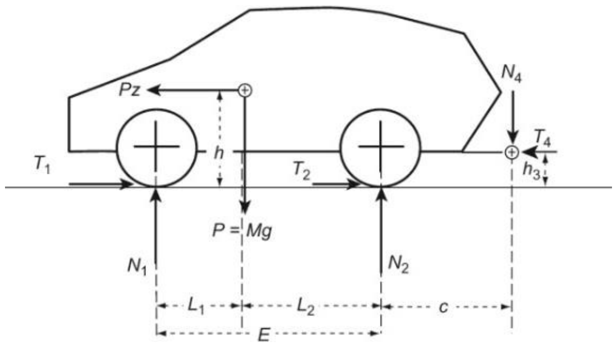

Fig. 4.3. Forces acting on the trailer. [3]

The parameters represented in the above figures are:

M_t – the mass of the trailer (kg),

P_t – trailer weight (N),

h_2 – the height of the center of gravity of the trailer above the roadway (m),

h_3 – height of the towing coupling above the wheel track (m),

E_2 – horizontal distance from the trailer coupler to the axle of the trailer wheel (m),

a_2 – horizontal distance from the center of weight of the trailer behind the trailer coupler (m),

a – the horizontal distance from the rear axle of the motor vehicle to its tow coupling (m).

The system of equations is:

$$N_1 - P + N_2 - N_4 = 0. \qquad (4.1)$$

$$T_1 + T_2 - P_z - P_4 = 0 \qquad (4.2)$$

Drivers of passenger cars towing trailers should pay attention to the trailer coupling load on the trailer hitch. This is extremely important from a legislative point of view but also from the point of view of wear on the rear axle of the towing car.

The average force of the coupling on the trailer hitch should be between 5% and 7% of the weight of the empty trailer plus load.

Analysis of the braking system for vehicle-trailer combinations is more complicated than for a simple two-axle vehicle because the sum of the forces acting on the trailer is not equal to the weight of the towing vehicle. The forces acting on the vehicle axles are functions of trailer loading and braking.

When driving a car with a load on the towbar, driving a car is completely different from driving without a trailer. When considering towing a trailer, some of the most important aspects to consider for safe driving can be listed.

As the car-trailer combination has different dimensions compared to a conventional passenger car, the behavior of the combination in cornering, overtaking maneuvers and other dangerous situations must be taken into account. Towing a trailer increases the braking distance, but especially the driving dynamics.

The braking performance of a passenger car towing a trailer in relation to the deceleration value required by the European standards shall be determined with the trailer attached to the passenger car. It shall not be less than 5,4 m/s^2 , both with the trailer laden to its maximum mass and unladen. [59].

Determination of the deceleration when braking with a trailer without a braking system is performed according to the formula:

$$\mathrm{d_{M+R}} = \mathrm{d_M} \cdot \frac{\mathrm{P_M}}{\mathrm{P_M+P_R}} \qquad (4.3)$$

where:

d_{M+R} – average deceleration of the vehicle coupled with a trailer without brakes, calculated [m/s^2];

d_M – the maximum mean deceleration of the vehicle obtained during the Type 0 test with engine disconnected [m/s^2];

P_M – mass of the vehicle (laden):

P_R – the maximum mass of a trailer without brakes which can be coupled as specified by the vehicle manufacturer.

The deceleration motion of a vehicle can be described by: distance, time, speed and deceleration. Distance and time are fundamental quantities, and velocity and deceleration are quantities derived from distance and time, which can be divided into fundamental quantities. Vehicle deceleration can also be calculated by dividing the change in velocity by the time interval over which the change in velocity occurred [10].

5. CONCLUSIONS

The design of the braking systems of motor vehicles must comply with certain legislative aspects relating to road safety.

The following aspects should be taken into account when designing and checking braking systems: braking distance, braking duration and deceleration

The braking system of a motor vehicle is used for its entire period of service. Any failure of the system can lead to catastrophic consequences, therefore the braking systems must be maintained within the parameters throughout the life of the vehicle. For safe movement of a motor vehicle towing a trailer, particular attention must be paid to the following aspects (fig. 1.17; 1.18; 1.19):

– uniform load distribution on the trailer;
– the main load weight should be over the axle;
– a low centre of gravity is favourable;
– the load is not allowed to pass over the side wall;
– securing the entire load against sliding;
– compliance with specifications for minimum and maximum vertical load on the hook.

The dynamics of a car-trailer system are difficult to manage because of the stresses that occur and which can act individually or in combination on parts of the assembly.

Once a trailer is coupled to a passenger car, the braking distance can be as much as four times as long if the speed of the passenger car is doubled.

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