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Increasing The Safety Of The Vehicle Driver Using The Braking Distance Detectors

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Публиковались ли Вы ранее в журналах из БД Scopus/WebofScience – Да.
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Abstract The main causes of collisions during road traffic accidents due to violations of traffic rules by drivers of road vehicles are insufficient response speed of the braking system and an inopportune response of the driver to the presence of an obstacle. This increases the risk of injury. By using a device for determining the braking distance,we can reducethe risk of injury to drivers. The device can improve the accuracy of determining the braking distance value, as well as the driver’s awareness in the process of movement and prompt response to obstacles along the way. The dynamic gaugefor vehicles moving in a column is determined by their length and safety distance, which depends on the specific road conditions, the speed of the braking onset and the nature of the movement. The safety distance is determined by the reserve distance between the road vehicles, the distance traveled during the driver’s reaction time on braking and by braking distance. The algorithm of the experimental setup with the use of the proposed device andits speed of operation will eliminate the distance traveled by the road vehicle during the driver's reaction time, which will significantly reduce the risk of collision. The electronic unit contains analytical dependencies for determining the magnitude of the braking distance. It takes into account the real road conditions duringthe road vehicle movement, the value of the safe distance between the vehicles. The initial data for determining the critical distance between cars come from the unit for determining the distance, which produces the signal about the real distance between cars, automatically activating the brake actuator, warning the driver about the collision danger.

Key words: driver safety, braking distance, safe distance, braking system, dynamic gauge, driver reaction time

1. Introduction

Road traffic accidents (RTA) are a serious social, economic, moral, psychological and medical problem in the Russian Federation, due to the severity of their consequences. In the Russian Federation, according to statistics for 12 months of 2016, more than 41% of all road accidents are vehicle collisions (72605), in which 8662 people died and 111843 people were injured [1].

The problem of reducing the accident rate is complex and multifaceted. To implement the government's plans on the problem of road accidents, the Federal Target Program "Improving road safety in 2013 – 2020" has been additionally developed andapproved by the Government of the Russian Federation on October 3, 2013, No. 864. The following specific measures are stipulated "...increasing the level of active and passive safety of vehicles, first of all, by strengthening the requirements for the development and installation of structural elements on vehicles aimed at protecting the life and health of road drivers...". Measures taken at the federal and regional levels to reduce the accident rate on the roads of the Russian Federation made it possible to somewhat stabilize the situation in this area, creating a tendency for their decrease. However, the absolute figures and relative indicators of road injuries remain quite high [2-8].

The main number of road accidents occurred due to traffic violations by vehicle drivers. The most common causes of traffic accidents due to traffic violations by drivers were inconsistency of speed with specific road conditions, non-observance of the sequence of passage, non-observance of the distance, driving while intoxicated, driving into oncoming traffic, violation of the rules of passage at pedestrian crossings. More than thirty percent of the accidents represent incidental collisions [9-17], and the main reason is insufficient response speed of the braking system, untimely response of the vehicle driver to the presence of obstacles, which lead to an increase in the risk of vehicle collisions.

The goal is to improve the safety of vehicle drivers using a braking distance detector.

2. Materials and methods

The possibility of increasing the safety of vehicle drivers is realized through the use of a device for reducing the braking distance, which is an important task in solving the problem of reducing injuries. The effectiveness of the braking systems used in modern vehicles is determined by the various methods for assessing braking qualities. These methods are outdated and are not focused on the high-power supply and carrying capacity of Russianvehicles, and thus do not meet the modern requirements of the driver safety conditions. The imperfection of these techniques, when applied to modern vehicles, is manifested in a rather high error in calculating the speed of movement, the driver's reaction time to danger, the response speed of the braking system, which ultimately affects the reliability of determining the time and distance of the braking before obstacle [18-28].

3. Results

To increase the driver's awareness in the process of thevehicle movement and the responsiveness to obstacles on the way, the authors have developed and tested a device that helps to determine the length of the braking distance [18].

The device (Figure 1)consists of an electronic unit based on a programmable micro-controller (1), equipped with a sensor for determining meteorological conditions (2), sensors for determining the angular speed of thewheels'rotation (3) and a sensor for determining the force of pressing the brake pedal (4), which sends a signal to the actuator of thebraking system (5) automatically, without the participation of the driver. This will significantly reduce the response time of the braking system and lead to a decrease in the value of the braking distance, which will increase the safety of vehicle drivers and reduce material losses in case of accidents during group movement of vehicles.

The developed device also contains a unit for determining the distance between the vehicleand the obstacle (6)and an information display (7).

While driving,the processing of signals from sensors for determining the angular velocities of thewheels'rotation (3)and the sensor for the determiningthe meteorological conditions (2) occurs constantly. The signals from these sensors are processed in an electronic unit based on a programmable microcontroller (1). It counts the angular speeds ofthe wheels' rotation, the quality of the road surface, the speed of the braking system, the length of the braking distance and the acceleration of the vehicle slowdown.

The electronic unit based on the programmable microcontroller calculates the difference in the speeds of the vehicle in front of it and the vehicle on which this device is installed,taking into account the readings of the sensors for determining the angular speed ofthewheels'rotation (3) and the readings of the unit for determining the distance between the vehicles (6).

An electronic unit based on a programmable microcontroller (1)determines the maximum permissible braking distance on the basis of the calculated data, taking into account the state of the braking system and wearing surface [4, 5].

A collision hazard message appears on the information display (7) if the distance between the vehicles moving in the stream is less than the maximum permissible braking distance. With a critical approach of the vehicle, the actuator for activating the braking system (5) is automatically triggered, while, depending on the distance between the vehicles, the engine is braked, reducing the fuel supply. With a critical approach, the braking system is activated without the participation of the driver. In addition, the developed device, using a set of sensors, can act as anAnti-lock Braking System(ABS), which allows to achieve effective braking and reduce the braking distance. Thus, the device decreases the likelihood of collisions inthe same-direction and oncoming group traffic of vehicles, and, as a consequence, the safety of thevehicle drivers increases.

The electronic unit based on the programmable microcontroller (1) contains analytical dependencies for determining the magnitude of the braking distance, taking into account the real road conditions of the vehicle's movement and the value of the safe distance between vehicles. The initial data for determining the critical distance between road vehicles come from the unit for determining the distance between the vehicles(6). If a signal is received from the unit for determining the distance between the vehicles(6) that the real distance between vehicles is less than the estimated length of the braking distance, then the actuator for activating the braking system (5) is automatically triggered (turning on the braking system, reducing the fuel supply), and at the same time a corresponding signal is triggered to warn thedriver about the collision danger.

Determining the safe distance between the vehicle's moving in the traffic flow is necessary to ensure the safety of road users, as well as the driver's confidence when driving the vehicle.

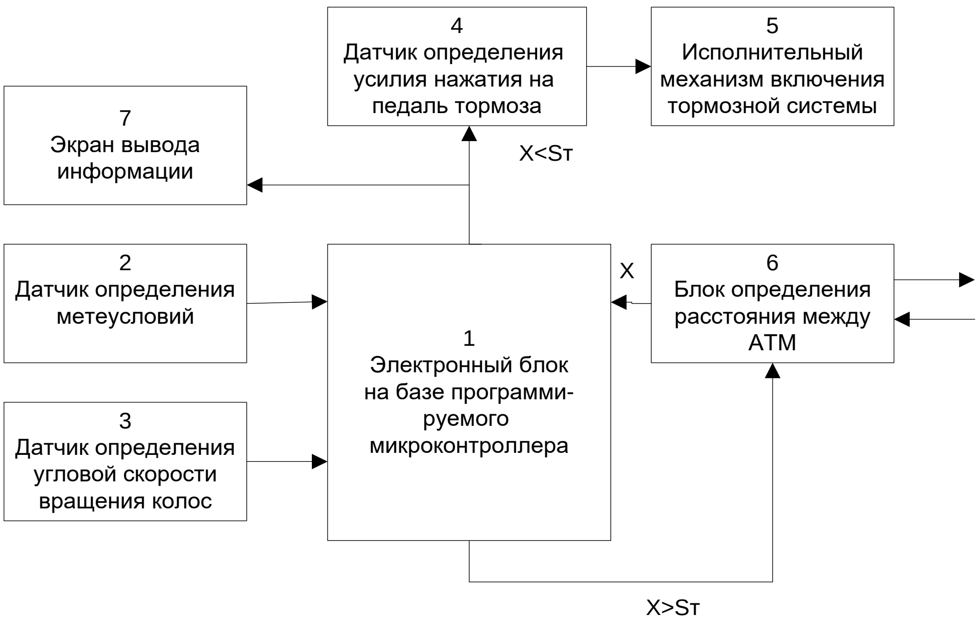


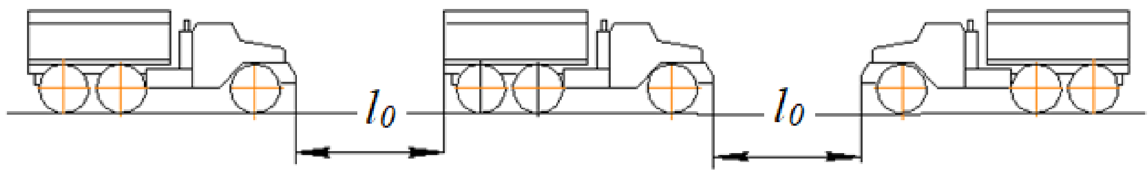
Figure1. Block diagram of the experimental setup

1 - electronic unit based on a programmable microcontroller; 2 - sensor for determining meteorological conditions; 3 - sensor for determining the angular speed ofthe wheels'rotation; 4 - sensor for determining theoperating force ofthe brake pedal; 5 - actuator for switching on the braking system; 6 - unit for determining the distance between thevehicles; 7 - information display

There should be enough distance between vehicles, so that the driver, having noticed an obstacle on the way, has enough time to realize the danger and make a maneuver to bypass it or stop in front of it [5].

The vehicles' safety is characterized by the safe distance between them, which depends on the movement speedand can be determined according to two calculation schemes (Figure 2).

a)



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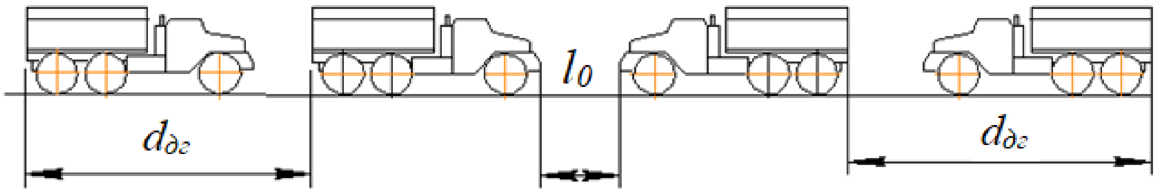

Figure 2. Calculation schemes

a)- in front of a stationary vehicle; b)- in conditions of oncoming traffic, s_T- braking distance of vehicles, l_0-safety distance between vehicles when stopping, $d_{дг}$-the vehicle's dynamicgauge

The distance covered by the vehicle during the driver's reaction time can be determined by the formula:

$l_1 = V_P(t_1 + t_2)$(1)

where:

t_1 - the time of the driver's decision to brake, s;

t_2 - tracking action time ofthe vehicle's braking system, s;

V_p - speed of thevehicle's braking onset, m/s;

Time t_1 depends on the driver's reaction and on the time during which he decides to brake and transfers his foot from the throttle pedal to the brake pedal.

Time t_1 also depends on the individual characteristics and qualification of the driver, usually t_1 is from 0.4 to 1.5 s. t_1 with value 0.8 s is usually taken for calculations.

The time t_2 depends on the design and technical condition of the brake gear, on the time during which the free travel of the brake pedal is selected, and the driver's control force is transmitted to the wheel brakes. For vehicles with hydraulic brake gear t_2 =0.2-0.4s and with pneumatic drive it is 0.6-0.8 s.

The timet_2 of a faulty hydraulic drive (in the presence of air in the system or faulty valves in the master brake cylinder) increases, the brakes are activated from the second (t_2= 0.6 s) or third (t_2≤1.0 s) pressing.

For vehicles with hydropneumatic brakes (for example, on the "Ural" chassis)t_2≤0.4 s. The time t_2 of all gears is reduced by the faster pressing of the brake pedal.

For the calculation in conditions of ensuring the possibility of the vehicle's stopping in front of an obstacle we can use the analytical dependence in accordance with the first scheme (Figure 2, a):

$$L_в = l_1 + S_m + l_0 = \frac{V_p}{3,6} + \frac{k_г \cdot V_p^2}{254 \cdot (\varphi_{np} + f_к)} + l_0, \text{ м} \tag{2}$$

The following dependence can be used for calculations in the condition of two oppositestopping vehicles moving at the same speed and from a slope (Figure 2, b):

$$L_в = 2l_1 + 2S_m + l_0 = \frac{V_p}{1,8} + \frac{k_г \cdot V_p^2}{127 \cdot \left(\varphi_{np} + f_к\right)} + l_0, \text{ м} \tag{3}$$

where: l_1 is the distance traveled by the vehicle during the driver's reaction time, m;

S_m - braking distance, m;

$k_г$ - coefficient of thebraking guarantee, $k_г$ = 1.4...1.7;

l_0 -safety distance between vehicles when stopping, l_0= 5...1m;

V_p - speed of the braking onset, km/h;

φ_{np} - reduced adhesion coefficientof the road surface;

$f_к$ - coefficientof resistance to the vehicle's movement.

The use of the first or second scheme for determining a safe distance depends on specific conditions and, above all, on the nature of the movement along the route. In our case, the application of the first dependence for one-waytraffic is considered, where the safe distance according to the calculation results will be about 50 m.

When vehicles move in a column, the safe distance between them depends on the specific road conditions, on the braking onsetspeed and the nature of the movement. In this case, it is necessary to introduce the concept of dynamic gaugeto determine the safe distance between vehicles.

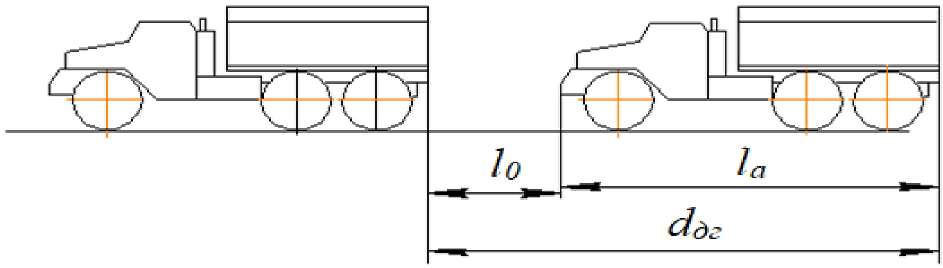

Figure 3. The structure of the vehicle's dynamic gauge

l_a- the average overall length of the vehicle moving in a column, l_0- the safety distance between vehicles when stopped, $d_{дг}$- the vehicle's dynamic gauge

The structure of the vehicle's dynamic gauge is shown in Figure 3.

The vehicle's dynamic gauge$d_{дг}$is determined by the length of the vehicle and the minimum safety distancerequired to safely stop a vehicle moving at a given speed [6]:

$$d_{дг} = l_a + l_0, \tag{4}$$

where: l_a is the average overall length of the vehicle moving in a column, m;

l_0 - the minimum safety distance required to safely stop the vehicle, m

$$l_0 = l \ + l_1 + S_m, \tag{5}$$

where: $l$is the reserve distance between vehicles, m;

l_1 - distance traveled by vehicle during the driver's reaction to braking, m;

S_m - braking distance, m

$$l_1 = 0{,}61 \cdot V_д, \tag{6}$$

$$S_m = 0{,}15 \cdot V_д, \tag{7}$$

where: $V_д$ is the average speed of the column, m/s.

The use of the above-mentioned calculation schemes and the corresponding algorithms in the developed by the authors device will improve the safety of theagricultural vehicles' drivers by automatically issuing a signal –a command from the computer of the electronic unit (4) to the actuator for activating the braking system (7) or affecting the fuel supply, with simultaneous light and sound signaling about reaching a dangerous approximation.

4. Discussion

The existing methods for determining the value of the braking distance are based on calculation-analytical and experimental methods and do not help to accurately determine the safe distance betweenvehicles.The existing systems and devices do not allow to measure the speed of each wheel of the vehicle due to the lack of control means for the values of the roadway slip coefficient. This reduces the information content for the driver in the process of movement due to the lack of instruments for measuring the angular velocities of the wheels. Existing systems also can't timely turn on the braking system due to the absence of an actuator for the brake automatic activation and a sensor of the brake pedal for measuring the pressing force, this fact reduces the response efficiency when an obstacle is found in the way. Whenusing existing systems and devices it isnot possible to determine the distance to the vehicle behind the driver due to the absence of a corresponding unit, this reduces the accuracy of determining the effective braking distance. Such option as establishing the basic parameters of the braking system due to differences in the characteristics of the braking dynamics of various vehicles models is also not available, resulting in the reduction of the accuracy for determining the effective braking distance. The actual systems do not take into account the psychophysiological specifics of drivers in the absence of an actuator for automatic activation of the braking system and a sensor for pressing the brake pedal, in fact, the timely activation of the braking system is not ensured.

5. Conclusion

Based on the above-mentioned, we can conclude, that:

-the developed and patented device for determining the vehicle's braking distance will improve the accuracy of determining the magnitude of the braking distance, the information content of the driver in the process of the vehicle movement and the responsiveness to the occurrence of an obstacle;

- the algorithm of the experimental setup helpsto reduce the distance traveled by the vehicle and exclude the distance traveled by the vehicle during the driver's reaction time, due to the fastresponse of the device. This significantly reduces the risk of collision and increases the safety ofdrivers;

- the developed and implemented experimental model of the device for determining the safe distance between the vehicles showed its efficiency in the real road conditions.

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