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MOVEMENT OF THE VEHICLE BEING BRAKED WHEN SOME WHEELS ARE INCAPABLE OF BRAKING OR HAVE LOST TOUCH WITH THE ROAD SURFACE

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Abstract. Movement of the vehicle when its certain wheels have lost contact with the surface of the road or cannot be held up through other reasons is considered in the present article. The vehicle deceleration and speed which is equivalent to the corresponding length of the braking trace of the wheels when all wheels of the vehicle are being held up and when its certain wheels have lost contact with the surface of the road or cannot be held up through other reasons are ascertained. The results of the computer experiment are presented.

Keywords: vehicle, wheel, dynamics, movement, deceleration.

1. Introduction

The interaction of the wheel with the road has been quite explicitly analyzed in the literature [1–6], however, the case when the vehicle moves with its wheels, having lost contact with the surface of the road, has not been hardly ever analyzed [7, 8]. Such movement is possible in the course of the traffic accident (for example, when the vehicle, being driven at a high speed, gets off the roadbed). Sometimes it's necessary to fix the vehicle parameters after its certain wheels loose contact with the surface of the road. You are usually faced with this problem when the wheels of the vehicle are being held up and leave traces which cease at a certain stripe (for example, when the vehicle, which is being braked, gets off the road slope). In the opposite case, when there are no any traces, it's almost impossible to ascertain if the vehicle wheels have lost contact with the surface of the ground and how far the vehicle has been moving like this.

2. Theoretical investigation

The deceleration of the vehicle after its certain wheels loose contact with the surface of the road may be ascertained in the similar way as in the case with the vehicle the braking system of which is out of technical order (when certain wheels of the vehicle cannot be held up), because, when certain wheels of the vehicle loose contact with the surface of the road, they, having lost contact with the surface of the ground, fail to hold the vehicle up (Table 1) [9].

Table 1. Deceleration of biaxial vehicles with the braking system which is technically out of order

Technical condition of the vehicle braking system	Deceleration j
One front wheel is incapable of braking	$\frac{(L+a)\varphi_k}{2L+h_c\varphi_k}g$
One back wheel is incapable of braking	$\frac{(L+b)\varphi_k}{2L-h_c\varphi_k}g$
Only one front wheel is capable of braking	$\frac{b\varphi_k}{2L-h_c\varphi_k}g$
Only one back wheel is capable of braking	$\frac{a\varphi_k}{2L+h_c\varphi_k}g$
The front wheels are capable of braking	$\frac{b\varphi_k}{L-h_c\varphi_k}g$
The back wheels are capable of braking	$\frac{a\varphi_k}{L+h_c\varphi_k}g$
The wheels located on one side are capable of braking	$\frac{\varphi_k}{2}g$

Remark: L – the vehicle base, m; a – the distance in between the vehicle's center of gravity and its front axis, m; b – the distance in between the vehicle center of gravity and its back axis, m; h_c – the height of the vehicle center of gravity; φ_k – the value of the cohesion coefficient for the definite vehicle in the definite road conditions; g – acceleration of the free falling down, m/s^2.

Being aware of the deceleration and the covered distance at each phase, it's possible to ascertain the

vehicle speed before the occurrence of the traffic accident according to the following formula (km/h):

$$V = 1{,}8 \cdot t_3 \cdot j_k + \sqrt{26(S_k \cdot j_k + S_1 \cdot j_1 + S_2 \cdot j_2 + S_3 \cdot j_3 + ... + S_n \cdot j_n)} = 1{,}8 \cdot t_3 \cdot j_k + \sqrt{26 \sum_{i=k}^{n} S_i \cdot j_i};$$

where t_3 is the time of deceleration increase, s; j_k is the vehicle deceleration when it has been held up on the road, m/s^2; S_k is the distance, covered by the sliding vehicle, m; $S_1 \ldots S_n$ is the distance, covered by the vehicle mass center at each phase, m; $j_1 \ldots j_n$ is the deceleration at each phase, m/s^2.

We shall compare the efficiency of holding of the vehicle up when its certain wheels have already lost contact with the surface of the road and cannot be held up. We shall ascertain the values for automobile VW PASSAT. The dependence of the vehicle deceleration upon the coefficient of cohesion after certain wheels of the vehicle, which is being help up, have lost contact with the surface of the road, is reflected in Fig 1.

We shall rate the vehicle speed (in this case VW PASSAT), which is equivalent to the length of the braking trace of a wheel or certain wheels (without taking into consideration the phase of deceleration increase) when all the wheels of the vehicles are being held up or when certain wheels are not being held up after they loose contact with the surface of the road or are not being held up through other reasons. The results of different cohesion coefficients (from 0,2 up to 0,8) are presented in Figs 2–5.

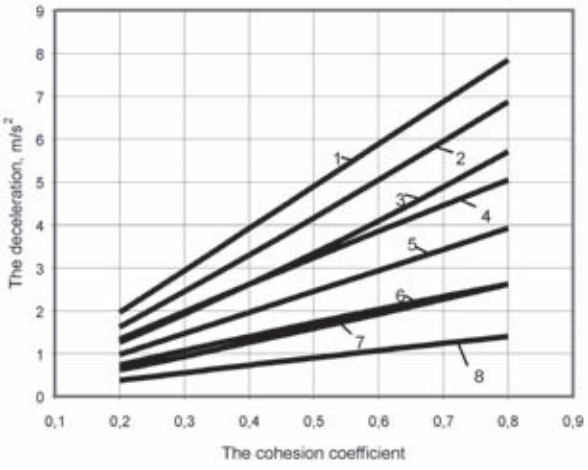

Fig 1. Dependence of the vehicle deceleration upon the cohesion coefficient after certain wheels of the vehicle, which is being held up, have lost contact with the surface of the road: 1 – all the wheels can hold up; 2 – the back wheel has lost contact with the surface of the road and cannot hold up; 3 – two back wheels have lost contact with the surface of the road and cannot hold up, i.e. only the front wheels can hold up; 4 – the front wheel has lost contact with the surface of the road and cannot hold up; 5 – the wheels, located at one side of the vehicle, have lost contact with the surface of the road and cannot hold up, i.e. only the wheels, located on the other side, can hold up; 6 – two front wheels have lost contact with the surface of the road and cannot hold up, i.e. only the back wheels can hold up; 7 – only the front wheel can hold up; 8 – only the back wheel can hold up

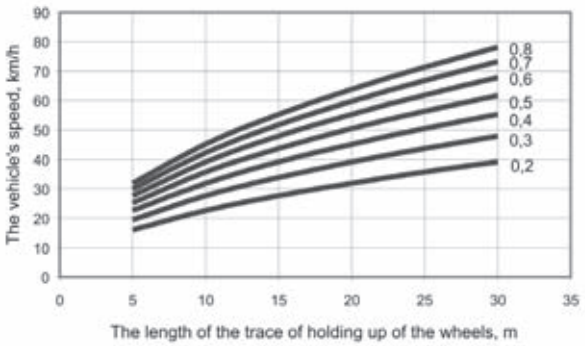

Fig 2. The speed of automobile VW PASSAT equivalent to certain length of the trace of braking when all wheels of the automobile can hold up

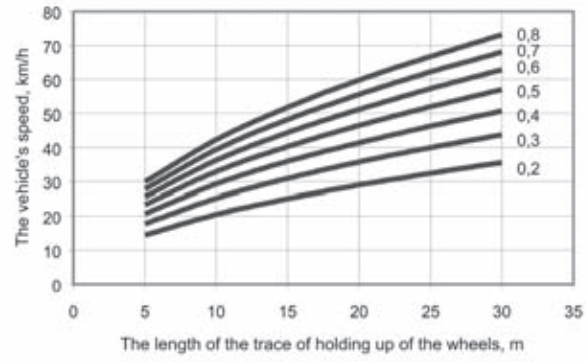

Fig 3. The speed of automobile VW PASSAT equivalent to certain length of the trace of braking, when the automobile back wheel has lost contact with the surface of the road and cannot hold up or cannot hold up through other reasons

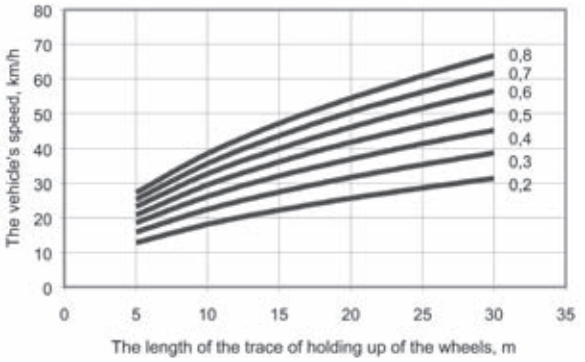

Fig 4. The speed of automobile VW PASSAT equivalent to certain length of the trace of braking when both automobile back wheels have lost contact with the surface of the road and cannot hold up or cannot hold up through other reasons, i.e. only front wheels can hold up

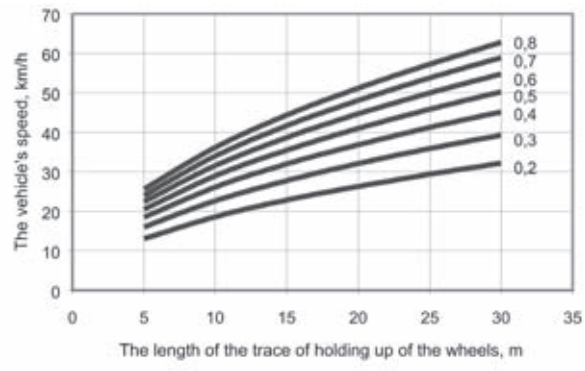

Fig 5. The speed of automobile VW PASSAT equivalent to certain length of the trace of braking when the automobile front wheel has lost contact with the surface of the road and cannot hold up or cannot hold up through other reasons

The thesis [10] reveals the analogous results when the wheels located on the one side of the vehicle or both front wheels of the vehicle cannot be held up after the wheels loose contact with the surface of the road or through other reasons; when only a front wheel of the vehicle, is being held up, or only a back wheel is being held up.

3. Computer experiment

Using the computer program PC CRASH 5.0 [11, 12], we shall model the movement of the vehicle which is being held up when its certain wheels cannot be held up. We shall model the movement of automobile VW PASSAT which has been analyzed, i.e. the automobile movement in the course of braking when its certain wheels have lost contact with the surface of the road or cannot be held up through other reasons. Let's assume that the automobile primary speed is 60 km/h.

The graphic reflection of modeling of the movement of automobile VW PASSAT when all its wheels are being held up is presented in Fig 6 (the distance in between the dots of the scale net is 1 m).

Fig 7 reflects the graphic view of modeling of the movement of automobile VW PASSAT when its back right wheel is not being held up.

As we see, the trajectory of the automobile movement in the course of braking deviates slightly to the left, when the automobile back right wheel cannot be held up. The trajectory of the automobile movement will deviate slightly to the right, if the automobile back left wheel cannot be held up. Fig 8 reflects the graphic view of modeling of the movement of automobile VW PASSAT when its both back wheels cannot be held up.

When the front right wheel of automobile VW PASSAT cannot be held up the automobile moves counter-clockwise around its vertical symmetric axle (Fig 9). The automobile would move clockwise, if the front left wheel cannot be held up.

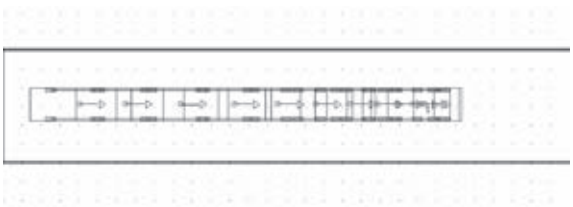

Fig 6. Movement of automobile VW PASSAT when all the wheels can hold up

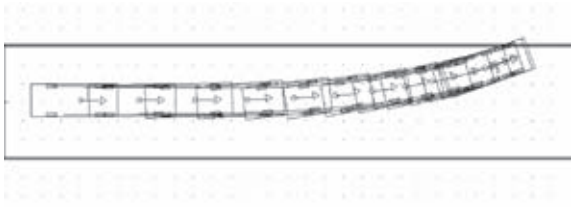

Fig 7. Movement of automobile VW PASSAT when back right wheel cannot hold up

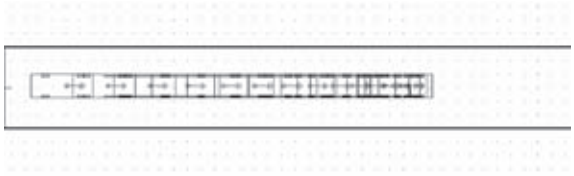

Fig 8. Movement of automobile VW PASSAT when a both back wheels cannot hold up

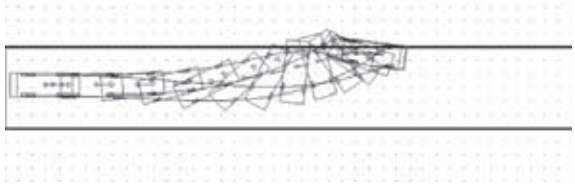

Fig 9. Movement of automobile VW PASSAT when front right wheel cannot hold up

The analogous modeling has been applied towards other cases, i.e. the cases, when the automobile wheels located at the right side both front wheels of automobile VW PASSAT cannot be held up; when only front left wheel can be held up; when only back left wheel can be held up [10].

The results of the computer investigation shall be summarized as follows:

- the error of the deceleration values when certain wheels cannot be held up because they have lost contact with the surface of the road or cannot be held up through other reasons which has been rated by theoretical calculation (Fig 1) and obtained in the course of computer modeling, does not exceed 2,8 %;

- the maximal error of the automobile speed which is equivalent to the corresponding length of the braking trace, is approximately 5 % .

4. Conclusions

1. According to the offered methods of calculation of the vehicle deceleration, when the vehicle, which is being held up, moves after its certain wheels have lost contact with the surface of the road, the dependence of the vehicle deceleration upon the cohesion coefficient, when certain wheels of the vehicle have lost contact with the surface of the road, has been ascertained (Fig 1).

2. The vehicle speed, equivalent to the corresponding length of the braking trace for different cohesion coefficients ($\varphi = 0{,}2...0{,}8$), when the wheels of the vehicle, which is being held up, have lost contact with the surface of the road or cannot hold up though other reasons, has been ascertained (Figs 2–5). The obtained results have been checked and evaluated in the course of the computer experiment.

3. The error of the values of the deceleration when the wheels of the vehicle, which is being held up, have lost contact with the surface of the road or cannot hold up through other reasons, which has been rated by theoretical calculation (Fig 1) and obtained in the course of computer modeling, does not exceed 2,8 %. The maximal error of the speed which is equivalent to the corresponding length of the braking trace is approximately 5 % .

4. There is a possibility to model the vehicle movement and to restore the course of the traffic accidents more precisely while carrying the examination of the traffic accidents.

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