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THE INFLUENCE OF STEP SHAPED ROAD SURFACE ON SAFETY WHEN DRIVING IN A BEND ON THE ROAD

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RESEARCH ARTICLE

ABSTRACT: The influence of the difference in the height of the road junctions e.g. when crossing the viaduct (dilatation), it can cause de-balancing of a vehicle, especially in the corners/bends. In practice, this differences in height can reach amplitudes (high of differences two asphalt planes) from 1 cm to 3 cm, or even more. However, anything larger than 1 cm can already represents the critical vertical movement of the vehicle that in combination with the vehicle speed, bend radius, the roughness of the asphalt, dry / wet roads, etc. can lead in catastrophic accident – especially by trucks. This paper, thus present analysis of tests and simulation of such vehicle behaviour, and correlate them with the observations from real occurred traffic accidents, related to this topic. Also concrete cases are shown.

KEY WORDS: *driving in bend road, speed limit in curve, side friction coefficient, vertical step on road, traffic accident*

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UTICAJ STEPENASTIH ISPUPČENJA NA POVRŠINI PUTA NA BEZBEDNOST VOŽNJE U KRIVINI

REZIME: Uticaj razlike u visini putnih čvorova npr. pri prelasku preko spojnica (dilatacija) može izazvati disbalans vozila, posebno u krivinama. U praksi, ove razlike u visini mogu dostići amplitude (velike razlike dve asfaltne ravni) od 1 cm do 3 cm, pa i više. Međutim, sve više od 1 cm već može predstavljati kritično vertikalno kretanje vozila koje u kombinaciji sa brzinom vozila, radijusom krivine, neravninama puta, suvim/mokrim asfaltom i sl. može dovesti do katastrofalne nezgode – posebno kamiona. U ovom radu je predstavljena analiza testova i simulacija ovakvog ponašanja vozila i dovedena u korelaciju sa zapažanjima iz stvarno nastalih saobraćajnih nezgoda, vezanih za ovu temu. Prikazani su i konkretni slučajevi.

KLJUČNE REČI: *vožnja u krivini, ograničenje brzine u krivini, koeficijent bočnog prijanjanja, vertikalni skok na putu, saobraćajna nezgod*

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INTRODUCTION

Centrifugal force in the bend/turn, $F_c = m \cdot a_r\_r = m \cdot v^2/r = m \cdot (\omega \cdot r)^2/r$, is depending on the radius of the curve (r), the mass of the vehicle (m), and radial acceleration i.e. speed through the corner. This causes the constant radial force on the wheel grip with road (perpendicular to the driving direction), throughout the corner. Any change in the height of the road surface, like a step, dilatation, bump, etc. can initiate the vertical movement of the car and thus on normal force that car acts on the road surface. Normal force of wheels on the road surface is assuring the sufficient friction between the tyre and the road that side movement of the car is prevented. With lowering the normal force, also the friction force is decreased [1]. In critical situation, when the tire for a moment loses contact, this means the normal force to the road surface will be zero and no friction will be assured. If this happens during driving through the corner/turn, the friction force cannot oppose the centrifugal force and the car will start uncontrollably moving radially from the corner/turn [2,3]. A sample case of such road surface has been analysed with the measurement of accelerations when driving through the in the corner. Results of the measurement are shown on Figure 1. The vertical step on the road surface, on the viaduct dilatation, can be recognised by a vertical amplitude in the signal (the diagram where the oscillation is recorded transversely to the direction of travel - at a time of 43.5 sec and close to 49 sec). From the other two graphs we can see that no impulse can be seen in the direction of the driving. However, in lateral direction, at a jump (periodic vertical bouncing of suspension) the slight peak can also be seen. At that moment, the car has driven over the vertical bumper on the road and caused the lateral movement. In this case higher periodic vertical amplitudes are observed after this excitation. Acceleration observed in vertical direction represents the decrease of the friction (that acts against the centrifugal force) for 50% ($F_{fr} = m \cdot g \cdot \mu = m \cdot (g - a_{vertical}) \cdot \mu$). Thus, from practical case we can see that the centrifugal force and lateral acceleration, as a result of cornering dilation, can cause the vehicle to skid and start to drift out of the corner. This is even more problematic in the situations where friction coefficient is, due to the weather conditions, significantly reduced (wet road, snow on the road) [4,5].

1. ACCIDENT CASE STUDY

On a wet road, where the friction coefficient decreases from 8 m/s^2 to e.g. 5 m/s^2, when the driver is already driving at a critical speed, the vehicle start skids in a corner even sooner [6,7]. This has happened in real situation accident of the track trailer driving over the viaduct/bridge. Additionally, we have to take into account the possible scenario of slipping of tires. When wheels/tires slip on a wet road, for a few moments, static friction changes to much lower dynamic one. This one is smaller and the vehicle can even faster come to situation that cannot resist the centrifugal force in the corner. Especially if the driving speed is too high or the corner radius is too small.

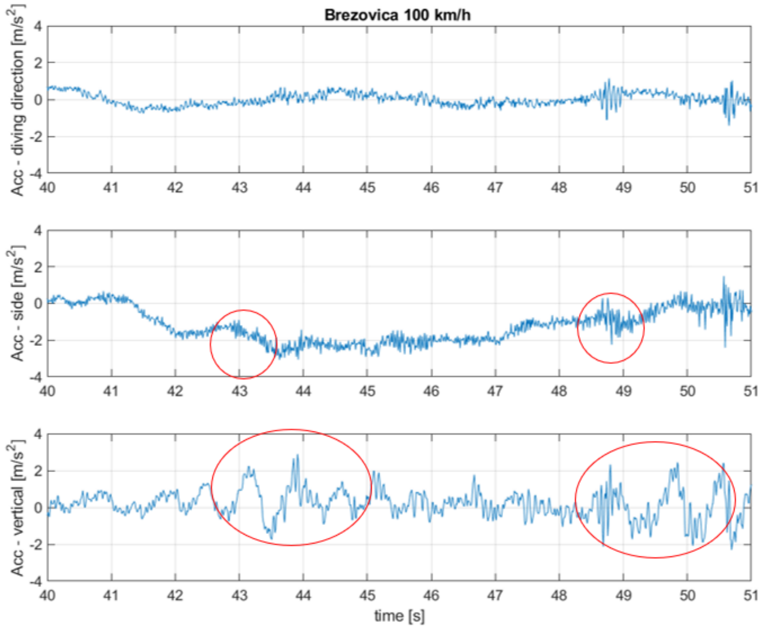

Figure 1 Accelerations acting on the car when driving through the corner with R = 300 m, and vertical dilatation step of 3 cm

The example that is show presents a traffic accident when an empty truck was moving downhill in a right-hand bend/turn with R = 100 m and on a wet road (Figure 2). The calculated speed exceeded the speed limit. The vehicle slipped while transporting the dilatation with a certain height difference out of the bend (centrifugal to the left), where it collided with the cabin in the opposite direction of a moving full truck. The empty vehicle bounced back to the right, over the bridge, through the railing and fell to a depth of 8 m.

Figure 2 Accelerations acting on the car when driving through the corner with R = 300 m, and vertical dilatation step of 3 cm

For the analysis, accelerations were measured in the corner and, as a result, due to the dilatation height drop, also transverse accelerations has been acting on the trailer. The results can be seen from the diagrams. It was found that this dilatation level difference also contributed to the vehicle slipping in the bend. Further, a critical situation arises when the sum of different factors cross composed limit value, where the vehicle comes to unstable region of behaviour, leading to radial slip or rollover. Overturning is largely influenced by the height of the centre of gravity. This is often the critical case for trucks, trailers, semi-trailers and tankers. If there is an additional lateral force in those situations, the balance is destroyed and the vehicle is evacuated centrifugally from the roadway. One of such examples can be show in Figure 3, where the truck is driving through the corner, close to the limit conditions (according to speed in a corner). In such a situation, a passenger car drifted into the front of the truck. Even though the passenger car has significantly lower weight, the impact was sufficient enough to de-balance the truck and cause that the tuck slide out of the bend, broke the concrete guardrail and fell to a depth of 15 m.

Figure 3 Centrifugal force (in turn) and radial hit force (by car) acting on a truck resulting on a catastrophic accident

2. RESULTS AND CONCLUSIONS

Based the shown analysis, it has been confirmed that the speed limitations have to be carefully defined. And at defining the right speed limit, the critical situation have to be predicted, and based on this defined the values that assure safety in everyday traffic. Contrary, even if the drivers are critical to those defined speed limits, they should follow them and not really judge whether they are appropriate. Those values are covering wide range of every day conditions (from most favourable to the most critical ones, i.e. wet road, high dilatations, bumps, dirt on the road, snow, etc.). Not following the recommendations, can cause as a consequence side skid of a car, etc. But of course, the base is the radius of the curve road, which is the primary reason for the lateral magnitude of the centrifugal force.

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