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THE INFLUENCE OF THE LATERAL ACCELERATION ON VEHICLE VELOCITY MOVING ON CURVED ROAD

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ABSTRACT

The movement of the vehicle in a curve related to the construction of the road is expressed through the influence of the radius of the curve and the transversal inclination of the road. Two of these parameters are fixed quantities ever since the projection and then construction phase of the road. During the vehicle's movement in the curve, their influence is shown through the critical slide velocity. This critical velocity is defined from the influence of the centrifugal force therefore lateral acceleration. Vehicle velocity is lower at the end of curve than in entrance, even when the driver is trying to keep constant velocity of vehicle, due to changes of lateral acceleration.

Key words: Lateral acceleration, radius, velocity, vehicle, measurement.

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1. INTRODUCTION

The velocity of the vehicle in the curve is influenced by the forces which move the vehicle, the resistances of the velocity and also the centrifugal force which attempts to displace the vehicle in the outer part of the curve or to displace from the desired trajectory of movement [1][2].

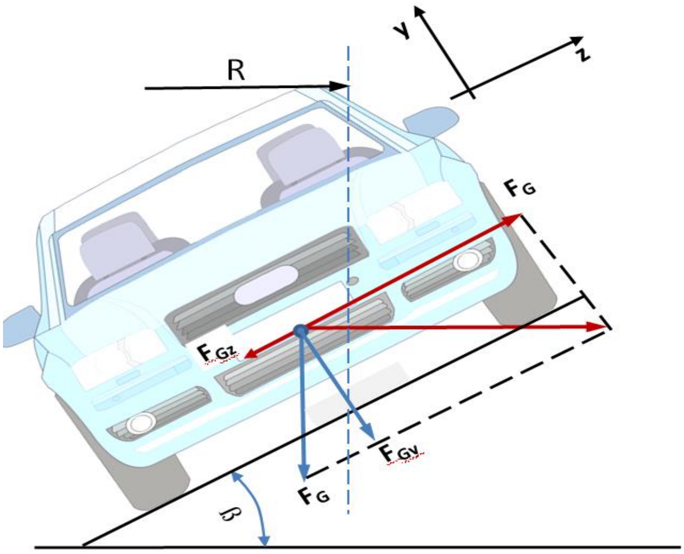


Figure 1 Forces which influence on the vehicle during movement in curve with lateral slope

The displacement from the trajectory is not immediate, but gradual and is realized through the slide into the side direction of the wheel proportionally to the surface of the road. For this reason, the critical slide velocity is accounted as criteria for the safety of movement of the vehicle [4]. Vehicle velocity in entrance and ending of the curve is different. At the end of the curve is lower than in entrance even the driver try to keep constant velocity [3] .

To keep same velocity should increase longitudinal acceleration, which than influence lateral acceleration. In this paper we are trying to explain the difference of vehicle velocity in the entrance and ending the curve through lateral acceleration.

2. THE EXPRESSIONS FOR DEFINING THE LATERAL ACCELERATION OF VEHICLE MOVING THROUGH CURVED ROAD

For the vehicle to be in the borders of stability the force of friction must be equal with the sum of the side forces. Meanwhile, to eliminate sliding towards the side in the direction of the radius of the curve, the sum of the forces on the Z axis must be lower or equal to the force of friction [5]:

$$\sum Fz = Fc_z - Gz - F_t = Fc \cdot \cos\beta - G \cdot \sin\beta - F_t \leq 0 \tag{1}$$

After the breakdown of the forces in the proper direction according to the axis, the transformations of the equations and the abstraction of smaller values (approximate to zero), the formula for the calculation of the vehicle's critical velocity is presented in this form [5], [12]:

- If the road in the curve with no transversal slope (angle $\beta = 0$ and $P = 0\%$), then the critical slide velocity is:

$$v_{rresh} = \frac{V}{3.6} = \sqrt{g \cdot R \cdot \mu_t} \quad \left[m/s \right] \tag{2}$$

Using expression (2), we can define lateral acceleration of vehicle moving through curved road in relation of vehicle velocity [9],[10]:

$$a_t = \frac{v^2}{R} \text{ [m/s}^2\text{]} \quad (3)$$

v-vehicle velocity [m/s]
R-radius of curve

Regarding the formula (2) is shown the relation between lateral acceleration of vehicle, vehicle velocity and radius of road curve. As higher is velocity of vehicle, also lateral acceleration get higher values. As higher values of radius of curve, we get lower values of lateral acceleration.

Table 1 Projected speed and radius of curve regarding of road category [11]

Category of the road	Projected Speed V_p [km/h]	Radius of the curve R_{min}[m]	Longitudinal slope [%]
Autoroad (Freeway)	80-120	250-750	4-6 (7)
Class I	70-100	180-450	5.5-7
Class II	60-100	120-450	5.5-8
Class III	50-90	80-350	6-9
Class IV	40-80	50-250	7-11
Class V	40-70	50-180	8-12

The values of the radius of the curve are dependent on the character of the road (the projected speed). According to the character of the road, the values of the radius of the curve are presented in table form. Regarding the table 1 we can get margins of lateral acceleration as per road category.

Analyses are done for the condition of dry asphalt road.

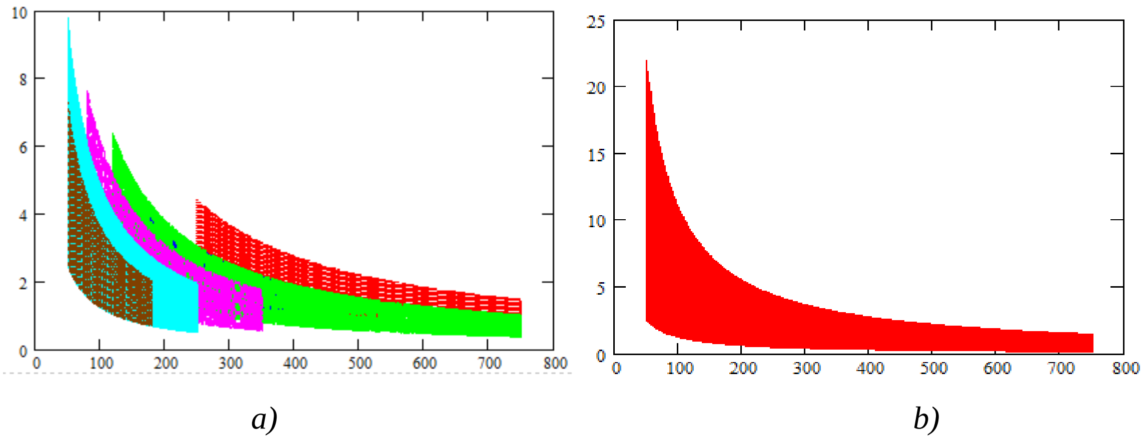
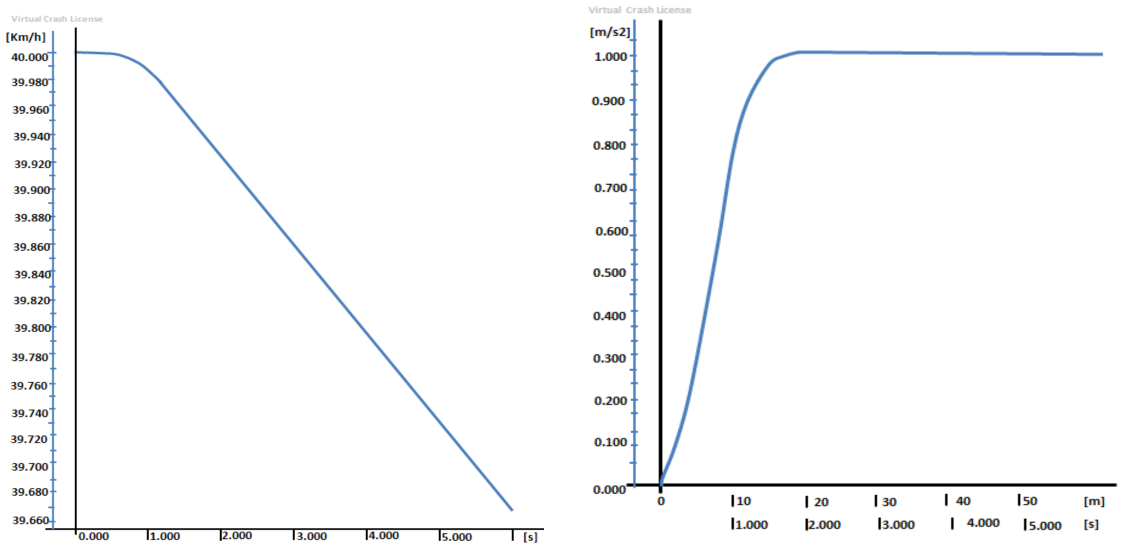


Figure 2 Margins of lateral acceleration: a) as per road category b) full range of values R and v

In fig.2 are represented two graphs of lateral acceleration per road category (fig.2.a). Road charts starts from right to left as shown in table 1. Second graph has one chart representing lateral acceleration by full range of values R and velocity v [13].

Regarding the fig.2 we assume that margins of lateral acceleration should be taken in consider only by road category (fig.2.a), because in case when values are taken in full range of R and v, values of lateral acceleration are out of range in real motion of vehicle (up to 22 m/s^2, fig.2,b).

In real motion of vehicle, velocity changes in the length of road curve. Intention is to keep the velocity constant. To explain this change we used simulation of vehicle motion through curve [6], [14].

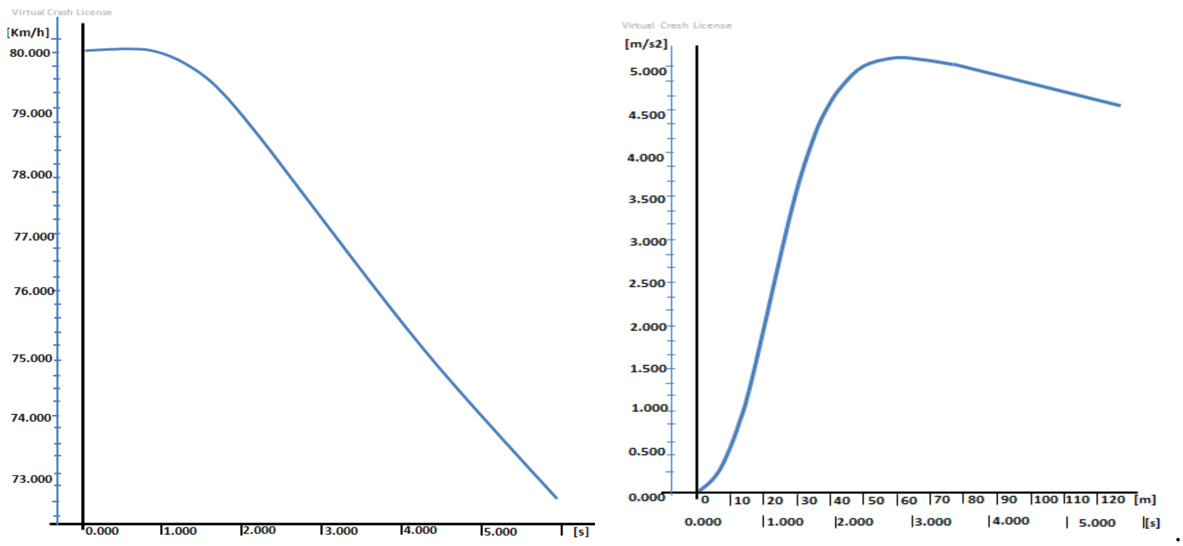


(a) *(b)*

Figure 3 Relation between lateral acceleration and changes of vehicle velocity (40 km/h)

In Fig.3 are represented two interconnected graphs: (a) graph representing relation between velocity and time of motion, and (b) graph representing lateral acceleration based on travel distance and time of motion. Initial velocity is 40 km/h, and initial lateral acceleration is $a_t = 0$ m/s^2. Travel distance is d = 55 m.

Based on graph in Fig.3.a, velocity decreases in time of travel through curved road; at the end of curve it drops with small difference. At the beginning is in curved form and after 2 s gets linear form. On the other hand, in Fig.3.b, lateral acceleration begins with lower values and increases in time, up to approx. $a_t = 1$ m/s^2. The form of curve is nonlinear until t = 2.5 s, and after that it has aprox. linear form.



a) *b)*

Figure 4 Relation between lateral acceleration and changes of vehicle velocity (80km/h)

In Fig.4 are represented another two interconnected graphs, similar to Fig.3. This time, initial velocity of vehicle is v = 80 km/h and maximal value of lateral acceleration is approx. a_t = 5 m/s^2. Difference of velocity drop is higher approx. D v =7.5 km/h (72.5 km/h at the end of curve). Noticeable is that travel distance is d = 120 m.

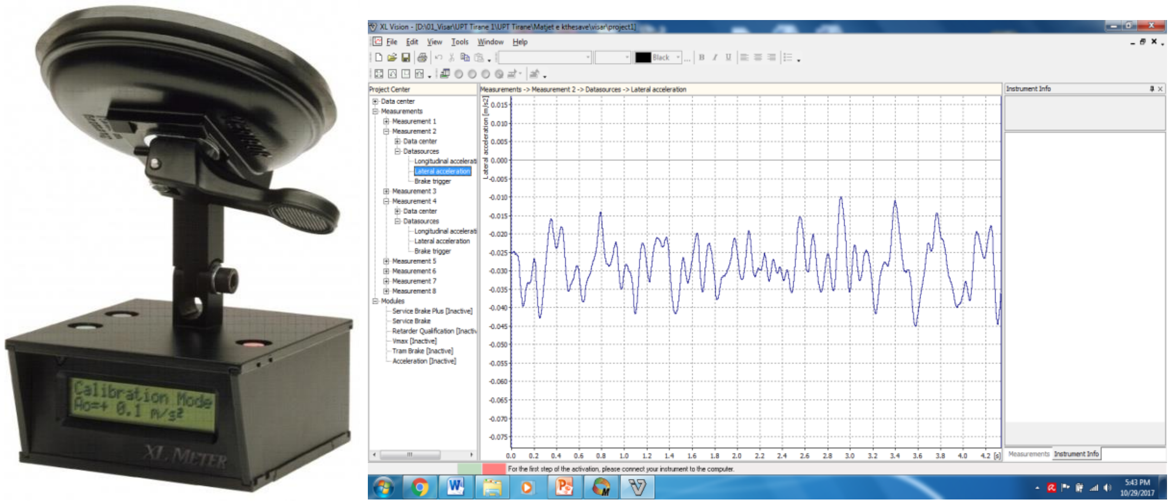


Figure 5 XL Meter Pro device for measurement of lateral acceleration with XL Vision software

3. EXPERIMENTAL MEASUREMENTS

Study is accomplished with experimental measurement using XL Meter Pro [15] device that measures Lateral acceleration and Brake performance (Fig.5). This device has ability to measure vehicle on movement, and gather results that can be exported graphically to its software XL Vision software [7], [15]. Measurement are done in curved roads with various turn radius [8].

Through measurements done with *XL Meter Pro* we got same conclusions: increasing the lateral acceleration brings higher difference of velocity from initial to the end of curve (Fig.6)

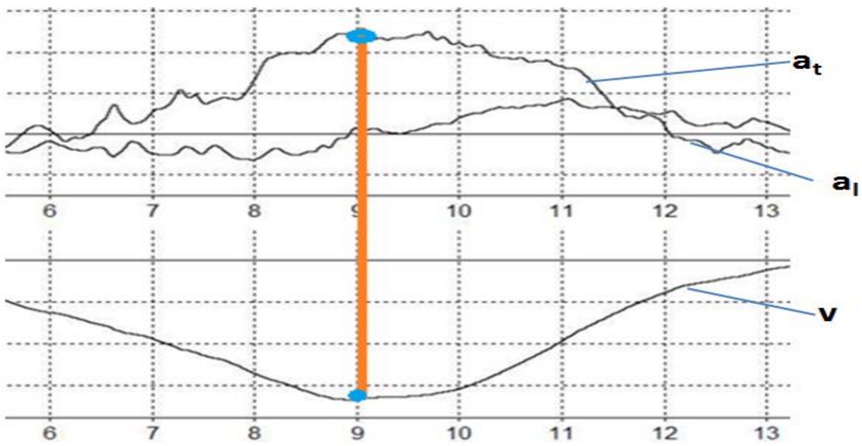


Figure 6 Measured lateral acceleration and changes of velocity of vehicle in curve

The graphs Fig.6. are given results of curves for lateral acceleration (a_t), longitudinal acceleration (a_l), and velocity (v), trough travel time (t). View of graph shows the same as simulations previously given in figures, that vehicle velocity is lower from initial velocity to the end or curve.

4. CONCLUSIONS

In this work we have presented analysis of vehicle movement in curved road, and influence of lateral acceleration on the vehicle during this motion.

While analyzing the numerical values of the vehicle velocity, in dependence with the change in the values of the lateral acceleration, we can conclude:

- The minimal values of the radius of the curve and higher vehicle velocity generate higher values of the lateral acceleration of the vehicle, with which we have lower comfort and safety of the driver and passengers,

- Vehicle velocity is lower than initial at the end of curve,

-Maximal values of lateral acceleration appears on the maximal turning angle of the curve,

- Increasing the values of lateral velocity brings higher difference of vehicle velocity at the end of curve from initial.

- For smaller values of lateral acceleration under critical velocity, this influence is expressed on the safety of movement and comfort of the driver and passengers in the vehicle.

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