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CONTRIBUTION TO ANALYSIS OF TECHNICAL POSSIBILITIES IN DESIGNING ARTIFICIAL HUMPS FOR VEHICLE SPEED LIMITATION

ABSTRACT

The purpose of this paper is to analyse the criteria that should be taken into consideration when designing the profile of the given humps that would force the drivers to maintain the desired speed limit and at the same time not to pose any threat on the stability of the vehicle itself and the stability of vehicle and traffic safety.

KEY WORDS

acceleration, vehicle, hump profiles

1. INTRODUCTION

It is generally known that in modern urban environment road vehicle drivers are forced to comply with certain traffic safety measures regarding the allowed speeds by construction of certain humps in the carriageway, the so-called speed humps. Practice has shown that such humps do not always provide optimal safety conditions related to the stability of driving as well as actually forcing the driver to abide by the stipulated and desired speeds. Some designs of these humps, namely, greatly endanger the stability of vehicle movement if the driver runs over them at excessive speed, which may result in traffic accidents. On the other hand, however, some hump designs have no effect on the vehicle, thus allowing the drivers to pass them without problems at speeds that greatly exceed those allowed.

2. MECHANICAL MODEL

Construction of speed bumps should:

1. Maintain the stability of vehicle movement,
2. Cause discomfort to the driver
   a. cause vertical acceleration,
   b. cause angular acceleration around the longitudinal vehicle axis,
   c. cause angular acceleration around the transversal vehicle axis.

Since humans are most affected by angular vibrations, it is obvious that this condition should represent the starting point in solving the actual problem. In or-

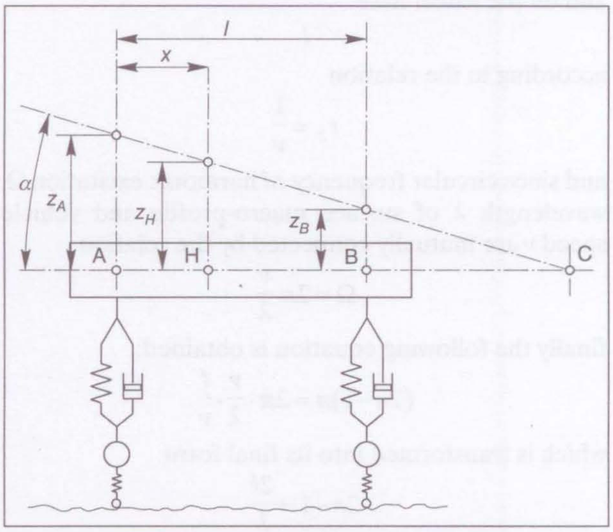


Figure 1 - Side view of the vehicle with respective values in passing over the humps on the carriageway

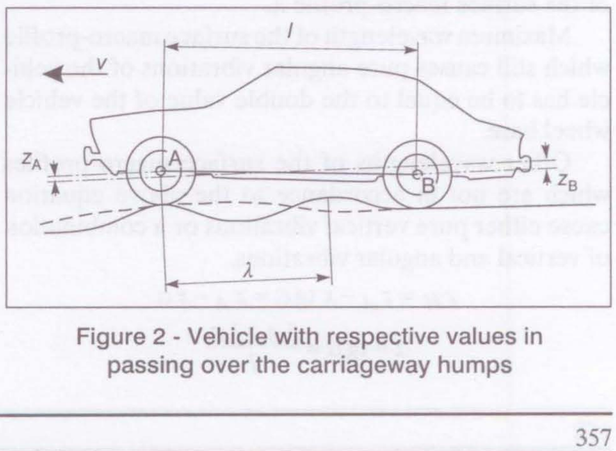


Figure 2 - Vehicle with respective values in passing over the carriageway humps

der to subject the driver in a vehicle to pure angular movement around the transversal vehicle axis, the carriageway macro-profile should be designed so that at every moment the vertical shifts of the front and rear part of the vehicle passing over the transversally laid humps are equal, but opposed.

If the harmonic excitation of the surface is circular frequency

$$\Omega$$

the desired vehicle kinematics will occur only if the vertical shift of the vehicle rear part lags behind the vertical shift of the front part of the vehicle by phase angle

$$(2n-1)\pi$$

which means that in that case the following equation needs to be satisfied

$$(2n-1)\pi = \Omega \cdot t_z$$

where

$$t_z$$

lagging time of the vertical shift of the vehicle rear part behind the vertical shift of its front part.

This time obviously depends on the vehicle speed

$$v$$

and on the wheel base

$$l$$

according to the relation

$$t_z = \frac{1}{v}$$

and since circular frequency of harmonic excitation Ω, wavelength λ of surface macro-profile and vehicle speed v are mutually connected by the relation

$$\Omega = 2\pi \frac{v}{\lambda}$$

finally the following equation is obtained:

$$(2n-1)\pi = 2\pi \cdot \frac{v}{\lambda} \cdot \frac{l}{v}$$

which is transformed into its final form

$$2n-1 = \frac{2l}{\lambda}$$

where n is the necessary number of surface waves, l is the vehicle wheel base, and the necessary wavelength of the surface macro-profile λ.

Maximum wavelength of the surface macro-profile which still causes pure angular vibrations of the vehicle has to be equal to the double value of the vehicle wheel base.

Other wavelengths of the surface macro-profiles which are not in accordance to the above equation cause either pure vertical vibrations or a combination of vertical and angular vibrations.

$$z_H = z_A - x\,\mathrm{tg}\,\alpha \approx z_A - x\alpha$$

$$\alpha \approx \mathrm{tg}\,\alpha = \frac{z_A - z_B}{l}$$

$$z_A = -z_B$$

$$z_H = z_A - x\frac{z_A + z_A}{l} = z_A\left(1 - \frac{2x}{l}\right)$$

$$\alpha = \frac{2z_A}{l}$$

$$z''_H = z''_A\left(1 - \frac{2x}{l}\right)$$

$$\alpha'' = \frac{2z''_A}{l}$$

Since during the harmonic movement the vertical shift of the front part of the chassis can be analytically expressed in the following form

$$z_A = C_A \cdot e^{i\Omega \cdot t} = A_A \cdot e^{-i \cdot \xi} \cdot e^{i\Omega \cdot t}$$

and since ξ, the phase shift of the front part of the vehicle chassis equals zero, because this part of the vehicle is the reference point of actual observation, it follows that the highest values of vertical and angular acceleration of the driver's seat are defined by relations

$$z''_H = A_A \cdot \Omega^2 \cdot \left(1 - \frac{2x}{l}\right)$$

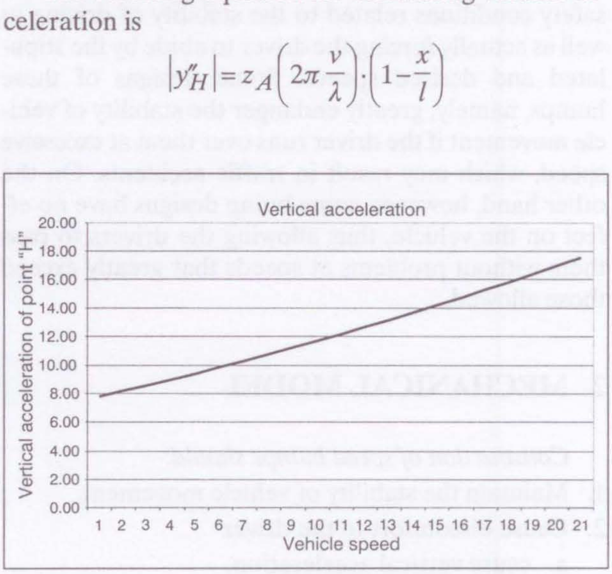
$$\alpha'' = \frac{2 \cdot A_A \cdot \Omega^2}{l}$$

where A_A is the amplitude of the vertical shift of the front part of the vehicle chassis in the position of the front wheels symmetry. In this way, by selecting the value of vertical and angular load on the driver's body, the necessary value of the vehicle chassis shift amplitude can be determined for any desired vehicle speed, and also the necessary carriageway macro-profile can be determined accordingly on the section where the vehicle speed needs to be restricted.

3. CONCLUSION

The resulting equation for calculating vertical acceleration is

$$|y''_H| = z_A\left(2\pi \frac{v}{\lambda}\right) \cdot \left(1 - \frac{x}{l}\right)$$



Speed	Acceleration
km/h	m/s^2
40	7,79
41	8,18
42	8,59
43	9,00
44	9,43
45	9,86
46	10,30
47	10,76
48	11,22
49	11,69
50	12,17
51	12,66
52	13,17
53	13,68
54	14,20
55	14,73
56	15,27
57	15,82
58	16,38
59	16,95
60	17,53

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SAŽETAK

PRILOG ANALIZI TEHNIČKIH MOGUĆNOSTI IZVEDBE UMJETNIH NERAVNINA PODLOGE RADI OGRANIČENJA ŽELJENIH BRZINA KRETANJA VOZILA

Cilj ovog rada je analizirati kriterije o kojima bi trebalo voditi računa pri izradi profila opisanih neravnina pod kojima bi se vozače vozila prisiljavalo na održavanje željenog ograničenja brzine kretanja uz istovremeno neugrožavanje stabilnosti samog vozila i stabilnosti vozila i sigurnosti prometa.

KLJUČNE RIJEČI

ubrzanje, vozilo, neravnina podloge

LITERATURE

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SOURCES

Figure 1 & 2: Master's thesis *"Influence of the Change in Carriage Profile on Vehicle Movement Stability"*, **Goran Zovak**, M.Sc.