ON „VZN" DAMPER BEHAVIOUR AT CRASH

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Abstract

Passive security at crash is an important problem both for road, and aerial vehicles, first case at horizontal collision and second at vertical one, on landing operation on ground or deck. Both generate human and material injuries, many of them with important negative effects.

Damper in bumper a known solution for vehicles protection at crash is realized with different damping devices, from passive elements to actuators. Usually the devices are tuned for 5 km/h crash speed and after collision the passive solutions destroy and must be replaced with other new devices. The solutions using standard shock absorbers and actuators are improper the first dissipating insufficient energy and actuators being more expensive and having a long reaction time so the damping coefficient changing is realized in too low steps.

VZN damper concept granted with European Patent EP 1 190 184 and Romanian Patent RO 1 185 46, characterized by progressive damping coefficients with the stroke assures protection at crash, due to its capacity to realize constant damping force without mechanisms and electronics, tuning damping characteristic to this desiderate.

The paper presents the differences between the energy must to be dissipated at the same crash speed in horizontal and vertical situation, it being increased at vertical situation, due to the gravity.

The same paper evaluates the advantages confers by VZN damper concept comparative to standard one, for both vertical and horizontal collision and concludes the VZN one is better 39% at vertical crash and 25% at horizontal crash comparative to standard one, due to its efficient dissipating system.

Keywords: *progressive damping, VZN, simulation, crash, passenger protection, body protection*

1. Introduction

The proposed self-adjustable shock absorber is called VZN, this acronym being abbreviation for Variable Zeta Necessary, for well displacement in all road and load conditions, where zeta represents the relative damping, which is adjusted automatically, stepwise, according to the piston position. The VZN shock absorber consists of an inner cylinder having sideways valves or metering orifices, inside a slidably piston moving. For VZN principle understanding, Fig. 1

presents from left to right three situations, with the piston in start, middle and ending position, on compression stroke. The number of active metering holes decreases, so the fluid flows out with increased resistance, generating increasing damping coefficients with the stroke. Thus, for VZN the damping force is adjusted stepwise, as function of the instantaneous piston position, i.e., both on rebound and compression the damping coefficients have: low values at the beginning of the strokes (the hydraulic fluid flows out through all the metering holes); moderate values at the middle of the strokes, for a good trade-off between comfort and wheel adherence (the hydraulic fluid flows out through half of the metering holes); high values in the working area between middle and end strokes, for better adherence and good axle movement brake (the fluid flows out through quarter of the metering holes); and very high values at the end of the strokes, for better body and axles protection (the fluid flows out through only one or two metering holes).

When the piston pass by the last valve/metering orifices the damping coefficient is multiplied comparative to the previous position, due to the fact the liquid flow is realized only in the gaps between inner cylinder – piston, so a hydraulic bumper are realized, eliminating the risk of metal on metal contact. So the rubber bumpers can be substantially reduces or eliminate, reducing costs and gauges.

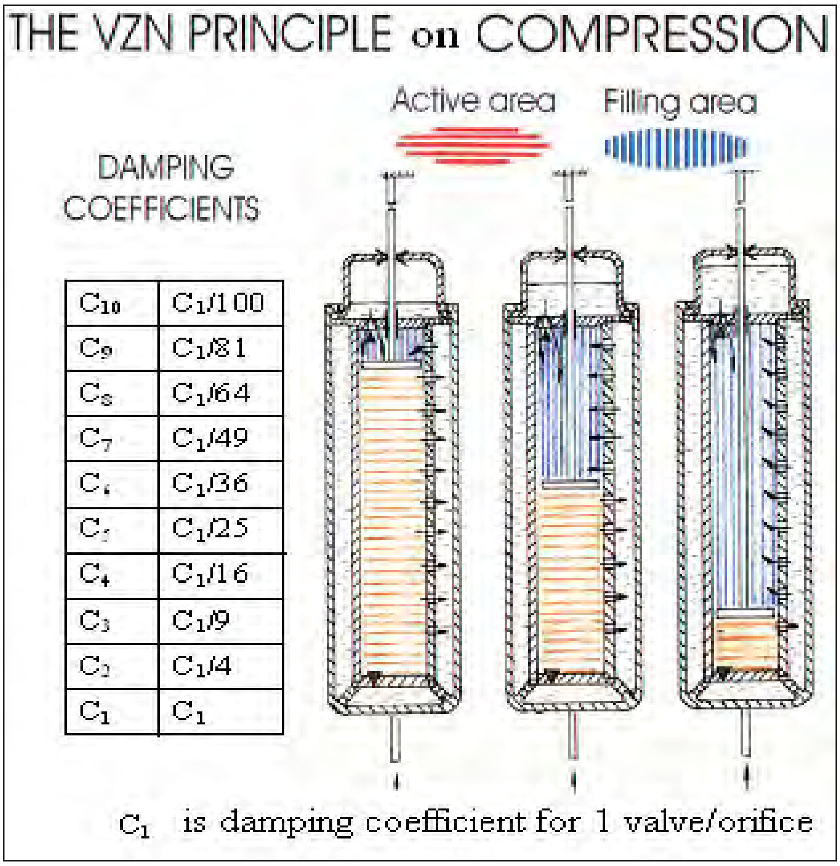


Fig. 1. The VZN principle and damping coefficients

2. The vertical crash simulation model

The virtual model is presented in Fig. 2, where from left to right are presented:

- the initial moment when chopper at the “H” height start free fall down,
- the moment of contact between chopper sledge/wheel and ground when started decelerated movement,
- the final moment when the damper had dissipated energy on the “h” distance.

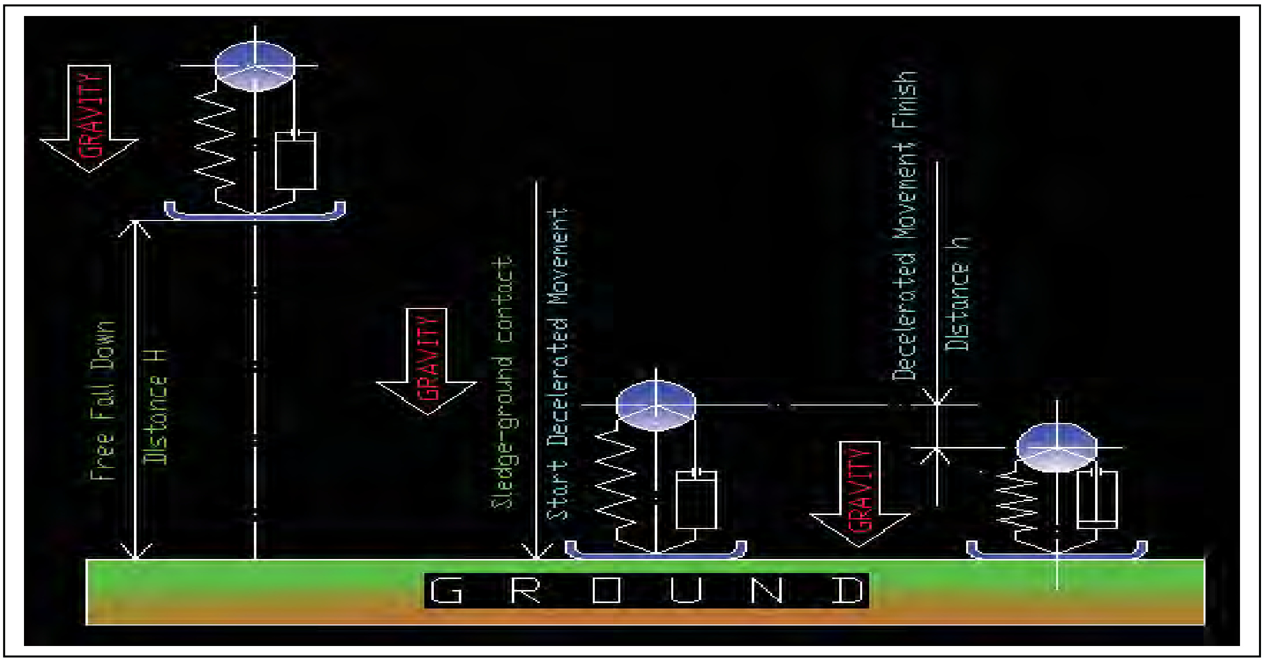


Fig. 2. The vertical crash model

3. The horizontal crash simulation model

The virtual model is presented in Fig. 3, where from left to right be presented:

- the initial moment when vehicle move with “V” constant velocity,
- the contact between vehicle bumper and obstacle, when started decelerated movement,
- the final moment when the damper had dissipated energy on the “s” distance.

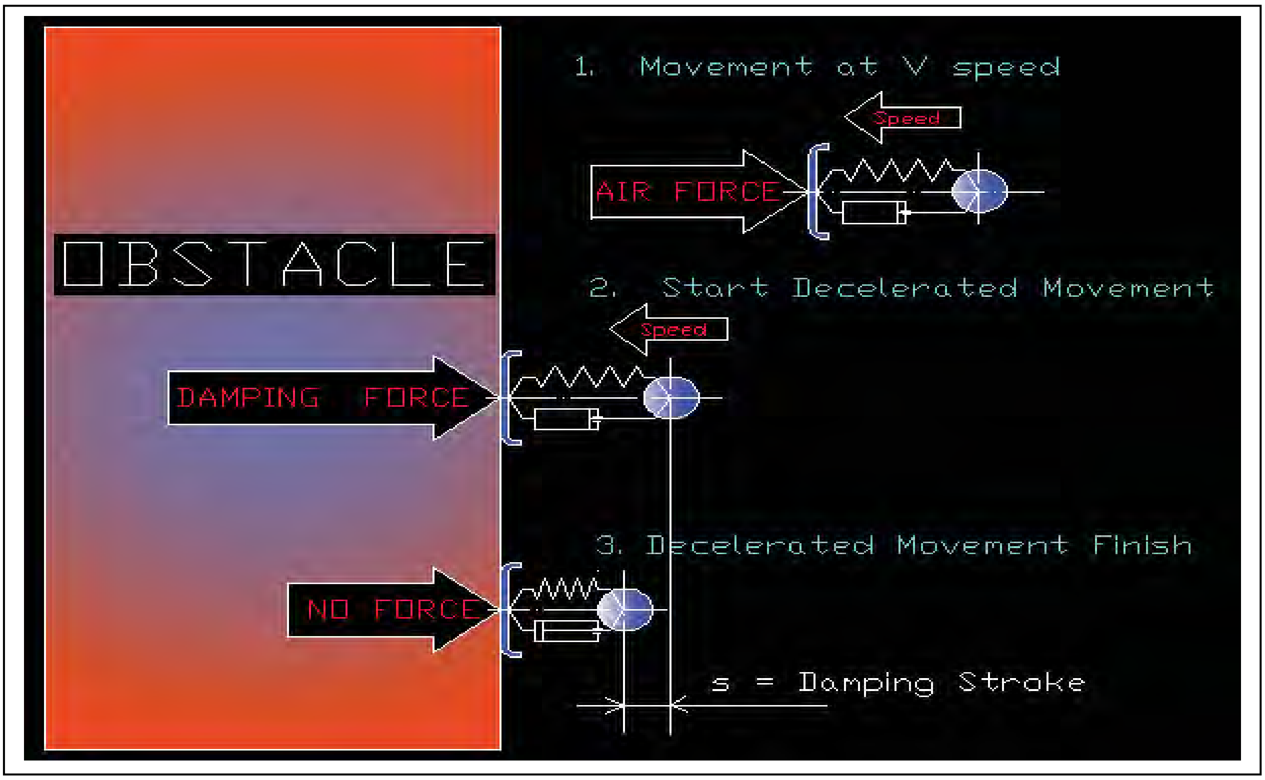


Fig. 3. The horizontal crash model

4. On vertical and horizontal energy to dissipate at crash

For efficiency at VZN the movement braking will be realized with constant force "F_d" given by:

$$F_d = md = m(\alpha g) = m(1 \div 9)g \, , \tag{1}$$

where:
"d" - the vehicle deceleration
"g" - the gravity acceleration

In both situations e.g. vertical and horizontal crash the total energy "E_T" to be dissipated is:

$$E_T = E_T^j = \begin{cases} E_T^V = E_k^V + E_p^V = mgH + mgh = \dfrac{mv^2}{2} + mgh = \dfrac{mv^2}{2} + mgs^V, \\ E_T^H = E_k^H = \dfrac{mv^2}{2}\, , \end{cases} \tag{2}$$

$$h = s^V \, , \tag{3}$$

$$E_d = F_d s = (md)s = [m(\alpha g)]s^j \, , \tag{4}$$

where:
E_T - the total energy to be dissipated to stop the movement,
E_d - the dissipated energy,
$E_T^j = \begin{cases} E_T^V - \text{the total energy to be dissipated to stop the movement, for vertical crash}, \\ E_T^H - \text{the total energy to be dissipated to stop the movement, for horizontal crash}, \end{cases}$
,
E_k^V - the kinematic energy to be dissipated to stop the movement, for vertical crash,
E_k^H - the kinematic energy to be dissipated to stop the movement, for horizontal crash,
E_p^V - the potential energy to be dissipated to stop the movement, for vertical crash,
E_p^H - the potential energy to be dissipated to stop the movement, for horizontal crash,
"v" - the speed in the first impact moment,
"h" - the braking height,
"s^j" - the damping stroke,
$s^j = \begin{cases} s^V - \text{the damping stroke for vertical crash}, \\ s^H - \text{the damping stroke for horizontal crash}, \end{cases}$
"H" - the height of free fall down.

5. Test conditions

The evaluation of the different behaviour conferred by VZN damper comparative to Standard one is made in both situations e.g. vertical and horizontal crash for deceleration "9g".

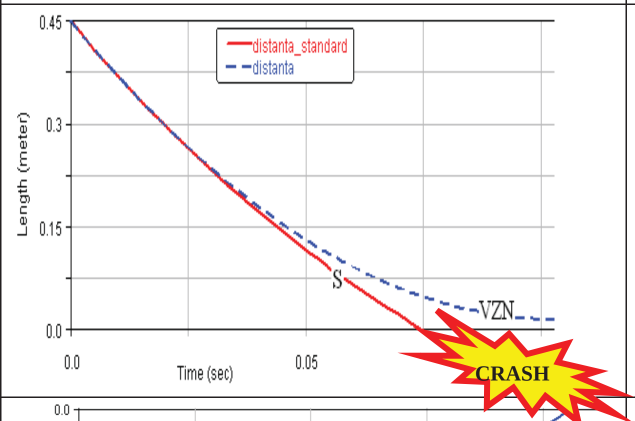
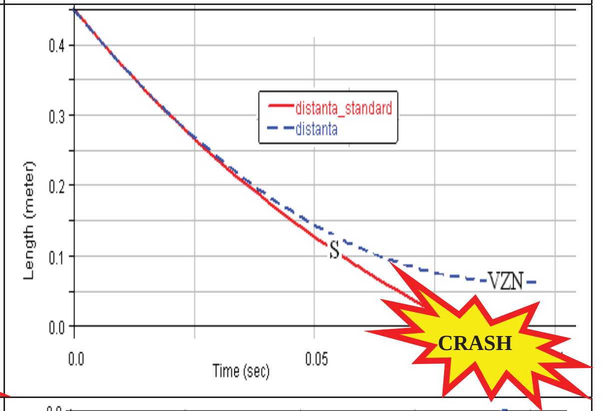
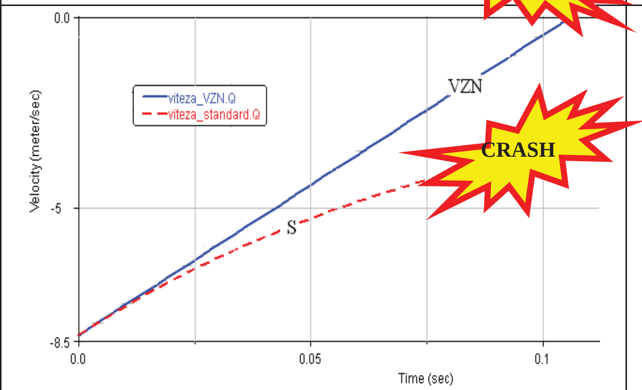
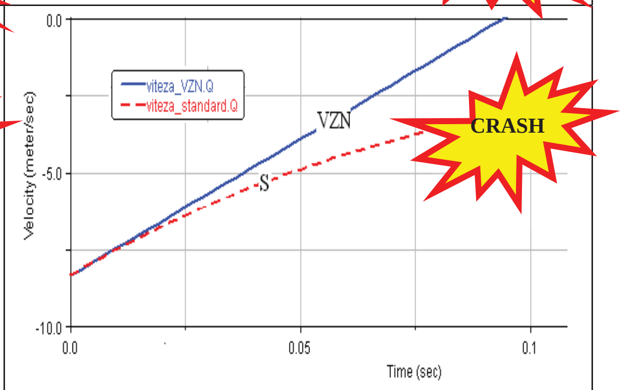
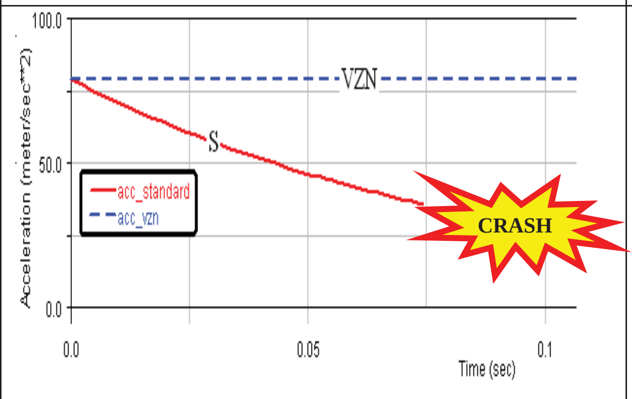
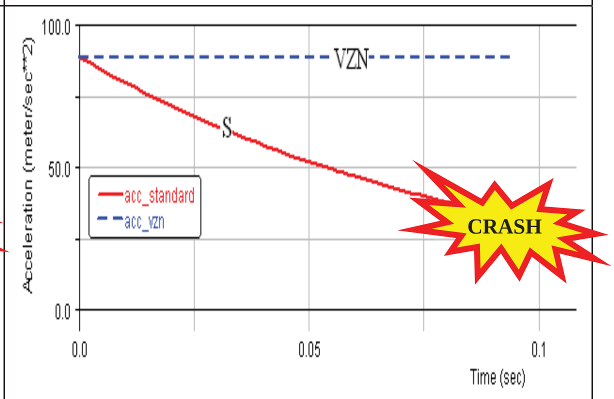
The damping force for VZN damper is constant along stroke, both cases. The other test conditions:

- the crash speed V = 30 [km/h],
- the vehicle mass m = 500 [kg],
- maximal damping force $F_{1500,9g}$ = 133000 [N],
- The damping coefficients for standard damper c_{30}^S = 16000 [Ns/m].

$$F_{m,d} = md = m(\alpha g) = F_{1500,9g} = 1500 \cdot (9g) = 1500 \cdot 88.29 \approx 133000[N], \quad (5)$$

$$c^{S}_{V^i} = \frac{F_{dMax}}{V^i} = \frac{F_{dMax}}{V_{30}} = \frac{133000}{\frac{30}{3.6}} = \frac{133000}{8.33} \cong 16000\ [N \cdot s/m]. \quad (6)$$

Tab. 3. Vertical and horizontal colli sion at V=30 [km/h], maxim deceleration "9g"and dampi ng stroke 0.45 [m], using VZN and standard dampers

Collision at V=30 km/h, with dampers tuned to decelerate with 9g on 0.45 m stroke		
	VERTICAL CRASH	HORIZONTAL CRASH
Distance [m]		
Velocity [m/s]		
Deceleration [m/s²]		
Conclusion	STANDARD damper crashes with 16 [km/h] $\Delta E_d^{S/VZN} = 28\%$ $\Delta E_d^{VZN/S} = 39\%$ VZN damper attenuate movement constant to 0 [km/h]	STANDARD damper crashes with 14 [km/h] $\Delta E_d^{S/VZN} = 20\%$ $\Delta E_d^{VZN/S} = 25\%$ VZN damper attenuate movement constant to 0 [km/h]

6. The simulation results

The simulations were made with ADAMS software View module, damping forces being realized using functions Impact, Contact and If and damping stroke being 0.45 [m].

All simulations show Standard damper can’t dissipates impact energy, crashing vehicle with 14-16 [km/h] speed, at the same time VZN one decreases speed to zero protecting the vehicle.

Energy "E_d^j"dissipated by both systems is:

$$E_d^j = \begin{cases} E_d^{VZN} = \dfrac{m\left[V_{crash}^2 - \left(V_{stop}^{VZN}\right)^2\right]}{2} = \dfrac{m\left[V_{crash}^2 - (0)^2\right]}{2} & - \text{ energy dissipated by VZN}, \\ E_d^S = \dfrac{m\left[V_{crash}^2 - \left(V_{stop}^{S}\right)^2\right]}{2} & - \text{ energy dissipated by Standard}, \end{cases} \tag{7}$$

where:

V_{crash} - are crash speed for VZN and STANDARD dampers,

V_{stop}^{VZN}, V_{stop}^{S} - are speed for VZN and STANDARD dampers at stroke end.

The STANDARD damper dissipating inefficiency "$\Delta E_d^{S/VZN}$" comparative to VZN one is:

$$\Delta E_d^{S/VZN} = \frac{E_d^{VZN} - E_d^S}{E_d^{VZN}} = \frac{\dfrac{mV_{crash}^2}{2} - \dfrac{m\left[V_{crash}^2 - \left(V_{stop}^S\right)^2\right]}{2}}{\dfrac{mV_{crash}^2}{2}} = \frac{\left(V_{stop}^S\right)^2}{V_{crash}^2}, \tag{8}$$

The VZN damper dissipating inefficiency comparative to STANDARD one is:

$$\Delta E_d^{VZN/S} = \frac{E_d^{VZN} - E_d^S}{E_d^{S}} = \frac{\dfrac{mV_{crash}^2}{2} - \dfrac{m\left[V_{crash}^2 - \left(V_{stop}^S\right)^2\right]}{2}}{\dfrac{m\left[V_{crash}^2 - \left(V_{stop}^S\right)^2\right]}{2}} = \frac{\left(V_{stop}^S\right)^2}{V_{crash}^2 - \left(V_{stop}^S\right)^2}, \tag{9}$$

According (8) the STANDARD damper is 28% less efficient than VZN at vertical collision and 20% less efficient at horizontal collision and according (9) the VZN damper dissipating efficiency comparative to STANDARD one is 39% increased at vertical crash and 25% increased at horizontal crash:

7. Conclusions

The paper presents the energy must be dissipated to attenuate the vertical and horizontal crash and the difference behaviour at these both situations, for VZN damper comparative to STANDARD one.

Both vertical and horizontal crash situation, VZN damper with constant damping force, attenuates constant the movement to “0’ speed protecting the passengers and vehicle, but STANDARD one cannot dissipate enough energy striking the vehicle with 16, respectively 14 [km/h].

Theoretical evaluation referring to the differences between energy at vertical and horizontal crashes is confirmed by simulation, the space of braking being lower at horizontal crash.

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