ON „VZN“ DAMPER BEHAVIOUR AT CRASH

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Abstract

On landing operation, a brutal contact with the deck or ground, can damage the plane or chopper and hurt the pilot, the crew or the passengers. The paper presents the advantages confer by suspensions using VZN dampers, in this situation. The Romanian self adjustable damper (shock-absorber) concept-VZN-granted with European Patent EU 1190184 and Romanian Patent 118546 assures damping coefficients increasingly by stroke from lower value up to the very high values, giving thus possibility to dissipate a huge energy at all speed regimes high, medium or low. With a convenient damping valve placement and/or dimension, the VZN concept confers possibilities to assure constant deceleration forces, at the human body limit resistance, this solution dissipating the maximal energy quantity.

The paper indicates solutions for VZN tuning in order to be used to realize constant deceleration at crash and developed one of them for a practical device realizes. The samples where developed so to be realized with components used in actual automotive shock absorber manufacturing, so prototypes being easy to realize.

Despite the simulations was realized considering standard damper dissipating energy function piston speed, not square piston speed, the standard damper dissipated 48.5% lower energy comparative to VZN one. This means in the same situation in which VZN damper reduces constant speed from 20 [km/h] to zero, the standard dampers reduces speed up to 11.5[km/h], then collapsing the aerial vehicle.

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 holes, 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. The situation is similar on rebound 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 tradeoff 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, on compression and between inner cylinder – piston and piston rod-guide on rebound, 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.

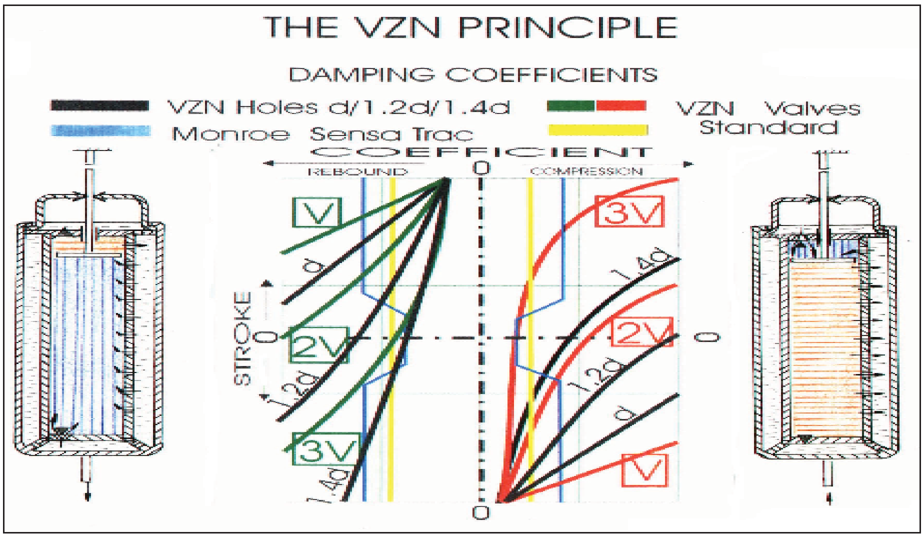

Fig. 1. The VZN principle, and damping coefficients, comparative with standard and Monroe Sensa Trac

2. A solution for “VZN” damping tuning to realize constant damping coefficient with speed

This solution consider the valve/metering orifices are placed at equal distance "δ"to each other.

Function of the "H" free fall down height, the body speed in the contact moment between undercarriage wheel/sledge and the ground is „V “

$$V = \sqrt{2gH}\ . \tag{1}$$

Because the cinematic energy varies with square speed we divide this speed area in “n” steps so the one step square speed is:

$$(\Delta V)^2 = {(V)^2}/{n}\ . \tag{2}$$

At the step “n” the beginning square speed is V_n^2 and final square speed is V_{n-1}^2, where:

$$V_n^2 = V_{n-1}^2 + \Delta V^2\ , \tag{3}$$

$$V_n = V\ . \tag{4}$$

The cinematic energy variation "ΔE_c" on a step „i“is:

$$\Delta E_{ci} = \frac{m}{2}(V_i^2 - V_{i-1}^2) = \frac{m}{2}\Delta V_i^2 = \frac{m}{2}\Delta V^2 = \Delta E_c\,, \tag{5}$$

where “m” being vehicle mass.

On a step „i“ the damper dissipates "ΔE_d" energy:

$$\Delta E_{di} = F_{di}\delta = F_d\delta = (c_i\overline{V}_i^2)\delta = \Delta E_d\,. \tag{6}$$

From these energy ΔE_c, ΔE_d equality results the equal distances δ between – metering orifices:

$$\delta = \frac{m\Delta V_i^2}{2F_{di}} = \frac{m\Delta V^2}{2F_d} = \frac{m\frac{V^2}{n}}{2F_d} = \frac{mV^2}{2mn\alpha g}\,. \tag{7}$$

The damping force is calculated at human body vertical admissible deceleration "d" like multiply "αg" of gravitational acceleration "$g = 9.81\ [m/s2]$":

$$F_d = md = m\alpha g\,. \tag{8}$$

For step “i” the damping force has expression:

$$F_{di} = c_i\overline{V}_i^2\,, \tag{9}$$

where:

"c_i" - is damping coefficient at the step "i",

"$F_{di} = F_d =$ constant" - is damping force, imposing constant along stroke,

"$\overline{V}_i$" - is average speed along step "i".

So the damping coefficients for each step “i”will calculate with relation:

$$c_i = \frac{F_d}{\overline{V}_i^2} = \frac{m\alpha g}{\overline{V}_i^2}\,, \tag{10}$$

$$\overline{V}_i^2 = V_i^2 - \frac{\Delta V_i^2}{2} = V_i^2 - \frac{V^2}{2n}\,. \tag{11}$$

The average speed at the final step "n" is calculated with relation:

$$\overline{V}_n^2 = V_n^2 - \Delta V^2 = V^2 - \Delta V^2\,. \tag{12}$$

The next average speeds for steps "i" are calculates with:

$$\overline{V}_i^2 = V_i^2 - \Delta V^2\,. \tag{13}$$

So all elements necessary to calculate the damping coefficients are defined.

3. Test conditions

For easy and fast behavior evaluation are used VZN and standard dampers, derived from rear Dacia Logan shock absorbers, tuned adequately. We consider the maximal safety inner pressure $p_{Max} = 100\ [khf/cm^2]$, so maximum force mast be:

$$F_{dMax} = p_{Max}A_{Crash} = p_{Max}A_C = p_{Max}(\pi\frac{D^2}{4}) = 100(\pi\frac{3.5^2}{4}) \approx 1000[Kgf] = 10000[N]\,, \tag{14}$$

where:

"p_{Max}" - the admissible inner pressure, in damper inner cylinder,

"A_{Crash}" - the active area at crash,

"A_C" - the active area on compression stroke,

"D" - the piston diameter.

The mass "m" corresponding "F_{dMax}" is:

$$m = \frac{F_{dMax}}{d} = \frac{10000[N]}{88.29[m/s^2]} = 113.263[kg] \approx 113[\mathrm{kg}], \tag{15}$$

where "d" is the constant deceleration.

The limit vertical deceleration for human body are:

$$d = \alpha g, \tag{16}$$

$$\alpha = (1 - 9). \tag{17}$$

The speed got after free fall down is:

$$V = \sqrt{2gH}. \tag{18}$$

The speed "V" is reduced at 0 by the damping system:

$$V = \sqrt{2dh} = \sqrt{2\alpha gh}, \tag{19}$$

where "α" is the

From equality of both "V" speed expressions results:

$$H = \alpha h = 9h = 9 \cdot 0.2 = 1.8 \text{ [m]}, \tag{20}$$

where "$h = S = 0.2$ [m]" is the dissipation height equal with the damping stroke (rear Dacia Logan shock absorber specific value).

The speed in the contact moment is:

$$V = \sqrt{2g(H-h)} = \sqrt{2g(1.8-0.2)} = 5.6[m/s] \approx 20.17[km/h]. \tag{21}$$

The standard damper gives constant damping force along stroke after formula:

$$F_{dMax} = c^S_{V^i} V^i, \tag{22}$$

$$i = \begin{cases} 0 - 1 \text{ - at low piston speed} \\ 1 - 2 \text{ - at medium piston speed} \\ 2 - 3 \text{ - at high piston speed} \end{cases}. \tag{23}$$

So the damping coefficients for standard damper for some "i" are:

$$c^S_{V^i} = \frac{F_{dMax}}{V^i} = \begin{cases} \dfrac{F_{dMax}}{V^1} = \dfrac{10000}{5.94} = 1785.71 \\ \dfrac{F_{dMax}}{V^2} = \dfrac{10000}{5.94^2} = 318.87 \\ \dfrac{F_{dMax}}{V^3} = \dfrac{10000}{5.94^3} = 56.94 \end{cases} \quad [N/_{m/s^2}]. \tag{24}$$

The maximum energy is dissipated if "i" is low, so in order to be covered we worked with "$c^S_{V^1} = 1785.71$". So the damping force for standard damper is:

$$F^S_d = c^S_{V^1} \cdot V = 1785.71\, V. \tag{25}$$

The damping force for VZN damper is constant:

$$F^{VZN}_d = 10000[N]. \tag{26}$$

We consider the suspension spring stiffness:

$$k = \frac{G}{S_G} = \frac{mg}{0.5S} = \frac{100 \cdot 9.8067}{0.5 \cdot 0.2} \approx 9807[N/m]. \tag{27}$$

The maximal spring force is:

$$F_k = kS = 9807 \cdot 0.2 \approx 1962[N/m]. \tag{28}$$

4. Simulation at free fall down, using VZN and Standard damping

In order to evaluate different behavior, at free fall down, given by VZN and standard dampers were used known VZN and standard dampers, utilized on Dacia Logan vehicle, so simulation and experimental evaluation will be easier realized and may take comparisons between simulation and practical tests.

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.

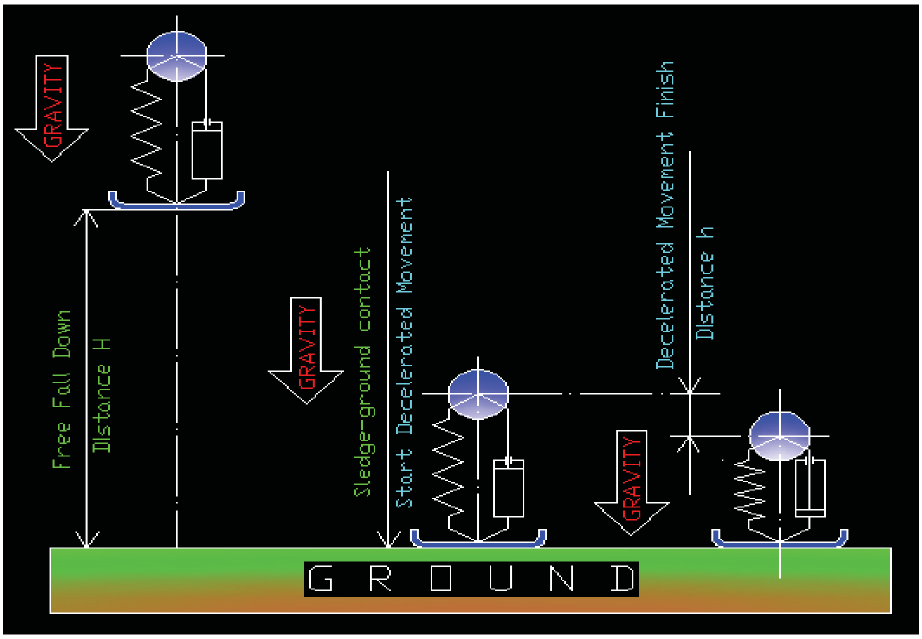

Fig. 2.The kinematic model

The speed and acceleration evolution for both kinds of dampers are presented in the Fig. 3-4. In blue color is presented the VZN diagrams and in red the diagrams for standard dampers.

The simulation indicates in similar conditions VZN dampers reduces constant speed to zero, but standard one up to 3.2 [m/s]=11.5 [km/h] generating chopper collapse.

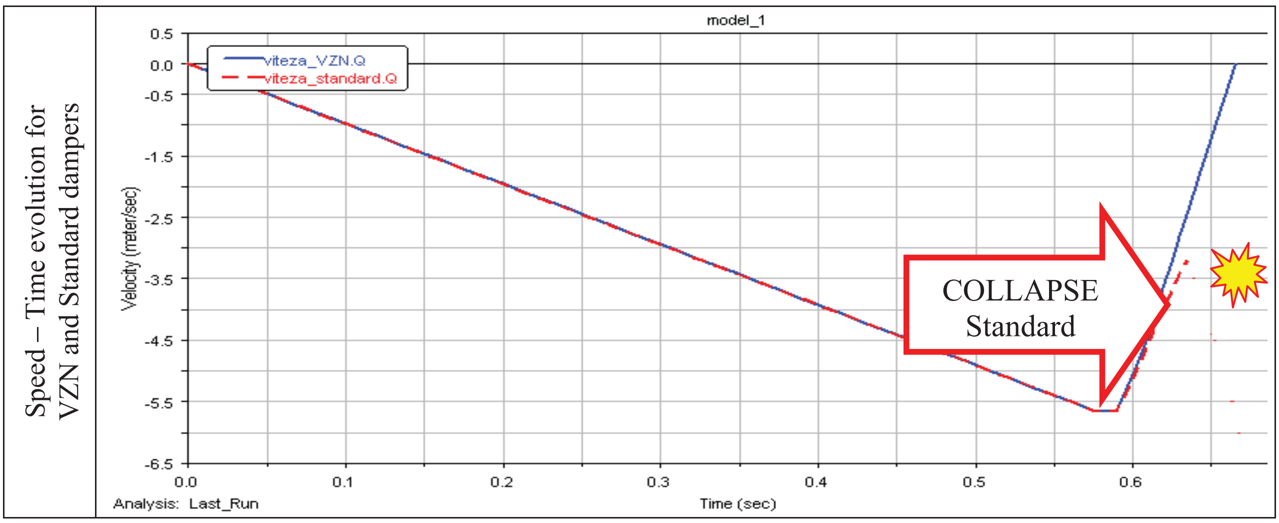

Fig. 3. The Speed – Time evolution for VZN and Standard dampers

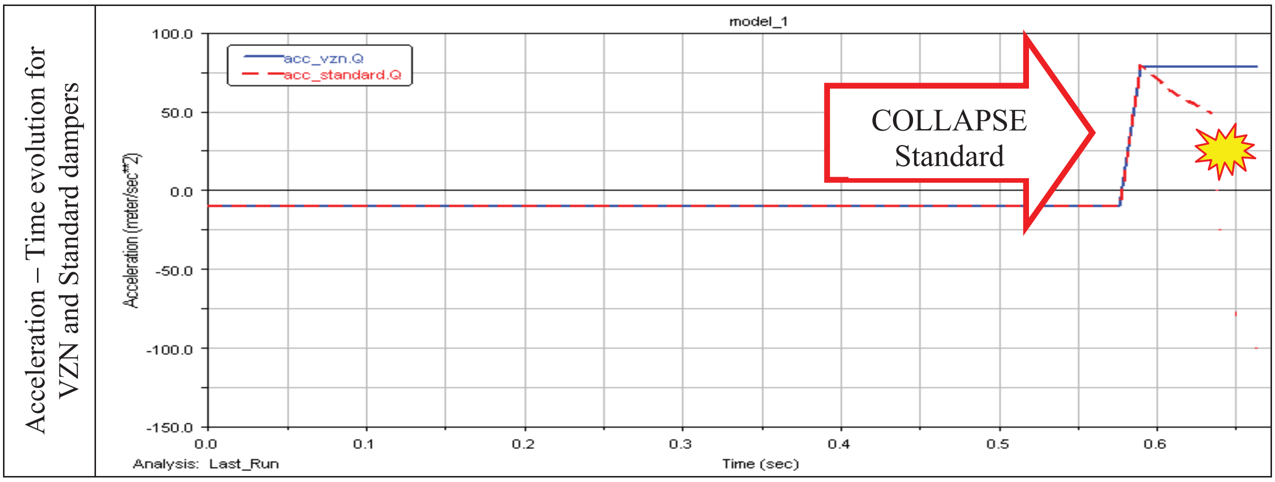

Fig. 4. The Acceleration – Time, evolution for VZN and Standard dampers

Energy dissipated by both systems are:

$$E_d^{VZN} = \frac{m(V_{VZNcontact}^2 - V_{VZNstop}^2)}{2} = \frac{113\cdot(5.6^2 - 0^2)}{2} = 1772 \text{ [J]}, \tag{28}$$

$$E_d^S = \frac{m(V_{Scontact}^2 - V_{Scollapse}^2)}{2} = \frac{113(5.6^2 - 3.2^2)}{2} = 1193 \text{ [J]}. \tag{29}$$

The energy dissipated difference "ΔE_d" is:

$$\Delta E_d = \frac{E_d^{VZN} - E_d^S}{E_d^S} 100 = \frac{1772 - 1193}{1193} = 48.5 \text{ [\%]}, \tag{30}$$

where:

E_d^{VZN}, E_d^S - are energies dissipated by VZN and standard dampers,

$V_{VZNcontact}$, $V_{VZNstop}$ - are initial piston speed for VZN and standard dampers,

$V_{VZNcontact}$, $V_{VZNstop}$ - are final piston speed for VZN and standard dampers.

5. Conclusions

The paper presents a tuning solution for the VZN damper (shock absorber) concept, to realize constant damping forces for a range of speeds being thus capable to be utilized at crash effect at free fall down eliminate. A standard and a VZN rear Dacia Logan shock absorbers were dimensioned to realize the same maximum deceleration. Despite in the first moment the standard damper realize the same deceleration with VZN damper, then it's damping forces decrease due to speed decreasing. Results indicates at the stroke end the VZN damper reduces constant speed to zero, but standard damper dissipated 48.5% less energy, reduces speed up to 3.2 [m/s], respective 11.5 [km/h] collapsing aerial vehicle.

References

[1] Niculescu, A. I., Alexandru, C., Jankowski, A., *A solution for crash and high ground uneveness effect reducing*, European Congress KONES, ISSN 1231-4005, Printed and bended in Poland, Vol. 15, No. 3, pp. 389-395, 2008.

[2] Niculescu, A. I., *On vehicles axles suspension, collision and rebuff decreasing*, chap.7 Research Trends in Mechanics, (eds. D. Popa, V. Chiroiu, I. Toma), ISBN 978-973-27-1574-1, Vol. 1, pp. 173-204, Romanian Academy Publishing House, 2007.