On the New Concept and Advantages of the Integrated Shock Absorber—Air Spring—"Isas"

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Abstract The paper reveal for the first time the novel concept of integrate shock-absorber-air spring, called shortly ISAS, and its advantages based simulations on quarter car model realized with ADAMS software-View module. ISAS is an easy and cheap solution for vehicle trim correction easy-going or in real time, to increase stability, comfort, passing capacity, handling, cruise speed and active security, reducing the risk of undercarriage damage. The novelty is to create a controllable buoyant force under the damper dust shield, by sliding closing the area between dust shield and outer cylinder and filling it with compressed gas/air at proper pressure. Comparative to the known solution realize with rubber sleeve/bellows the new proposed solution is more compact, reliable and resistant at high pressure, thus having possibility to fully eliminate the steel spring, his function being full taken by the air spring device contained by the ISAS product, situation reducing the cost comparative to the classic suspension. The "ISAS" trim corrector, has applicability on front and rear suspension including to the Macpherson solution, each vehicle kind including motorcycles, cars, buses, trucks, trains, military and racing vehicles, improving performances, comfort and transport security. The same the novel trim corrector has applicability in vehicle seats and cabin, increasing the

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comfort, visibility and thus the transport security. The ISAS solutions are in patent application no. A2015/00368—OSIM Romania. The ISAS concept advantages are demonstrates based simulation on a complex quarter car model equipped with rebound and compression stopper buffers and shock absorber equipped with adjustable pneumatic spring.

Keywords Trim corrector · Shock absorber · Air spring · Integrated · ISAS

How Realize Integrated Shock Absorber—Air Spring

To realize ISAS uses a standard damper and apply some minor modifications, presented below:

Step 1 replace the standard dust shield with other one resistant to pressure
Step 2 apply an annular body on the outer cylinder, the annular body containing one or more channels with one or more seal elements, their sealing lip/s sliding sealing on the inner surface of the new dust shield
Step 3 seal new resistant dust shield against rod with a seal member
Step 4 apply an air filling valve on the dust shield and connect it to a pressure air source, respectively to a compressed air tank or a compressor
Step 5 adjust manually or automatically the vehicle trim, by modifying the gas/air pressure

Figure 1 shows evolution from standard damper to integrated damper-air spring.

The components presented in Fig. 1 are explained in Table 1.

The elements 1 ÷ 8 are commune elements for both variants.

The washer 18 is utilized when the support shoulder of the rod 3 is enough.

In Fig. 2 are presented other two sealing solutions against the rod and filler rod solution.

In the Fig. 3 is presented solution for full trim control.

The main elements presented in Fig. 3 are:

206	air spring units C_1, C_2, C_3, C_4, controlling each semi-axle
117	pressure transducers
176	position transducers
14	source of pressured gas/air
209	pressured gas/air reservoir
205	electro-valves
145	analysis, command and control unit
149, 150, 206, 207	indicators for pressure, position, pitch and roll

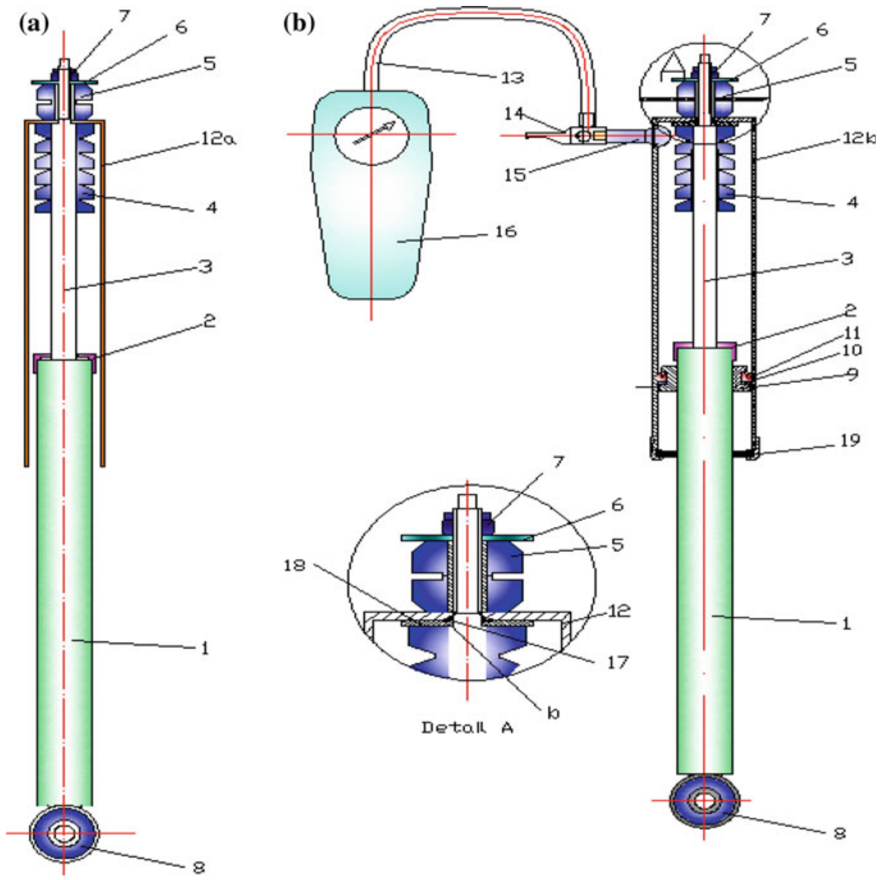


Fig. 1 The genesis of integrated shock absorber-air spring based a standard shock absorber. **a** The standard shock absorber. **b** Integrated shock absorber-air spring, realized based standard shock absorber from position *A*

Table 1 The components of standard damper and of integrated spring-damper

1	Shock absorber outer cylinder	11	Sliding sealing element
2	Annular anvil	12a	Dust shield
3	Rod	12b	Reinforced dust shield
4	Stopper buffer on compression	13	Pressure hose
5	Gripping pads	14	Quick plug
6	Washer	15	Quick valve
7	Self-locking nut	16	Compressor/pressure gas tank
8	Gripping bushing	17	Seal element
9	Annular piston	18	Special washer
10	Pusher ring (optional)	19	Dust brush

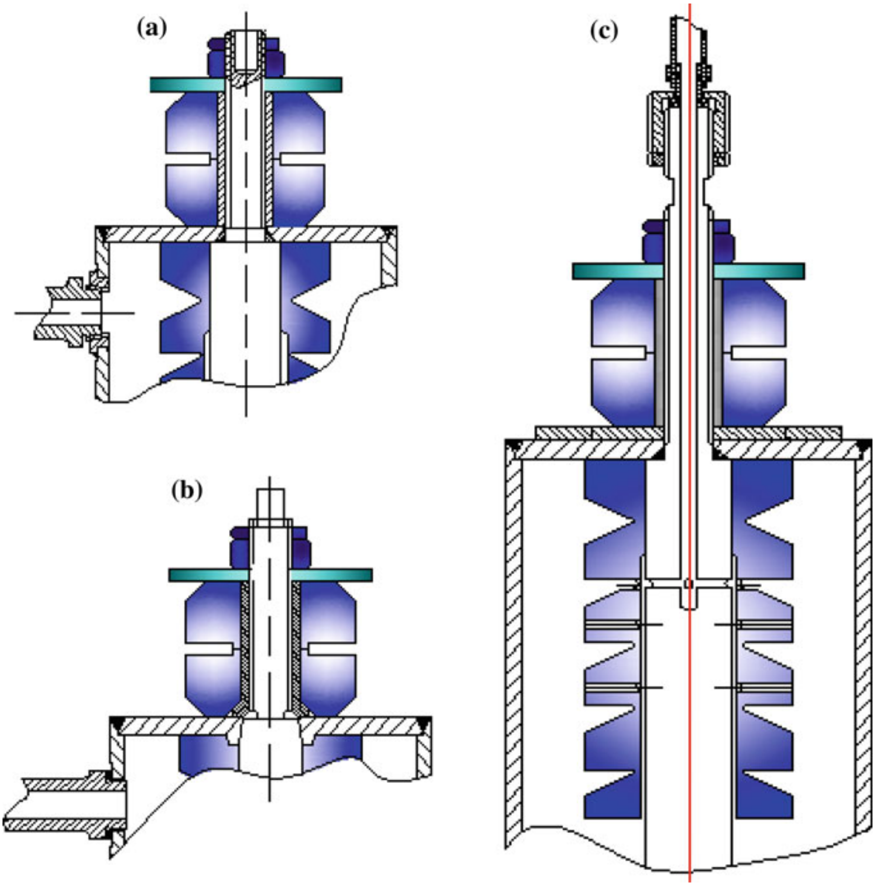


Fig. 2 Other sealing and filling solutions. **a** Sealing when the rod shoulder is enough. **b** Sealing by conical fit. **c** Filler rod solution

The Realized Integrated Shock Absorbers—Air Springs

The elements are the same presented in Fig. 1 and explained in Table 1, excepting the positions 19, 20, representing (Fig. 4):

20 centering ring
21 protecting seal

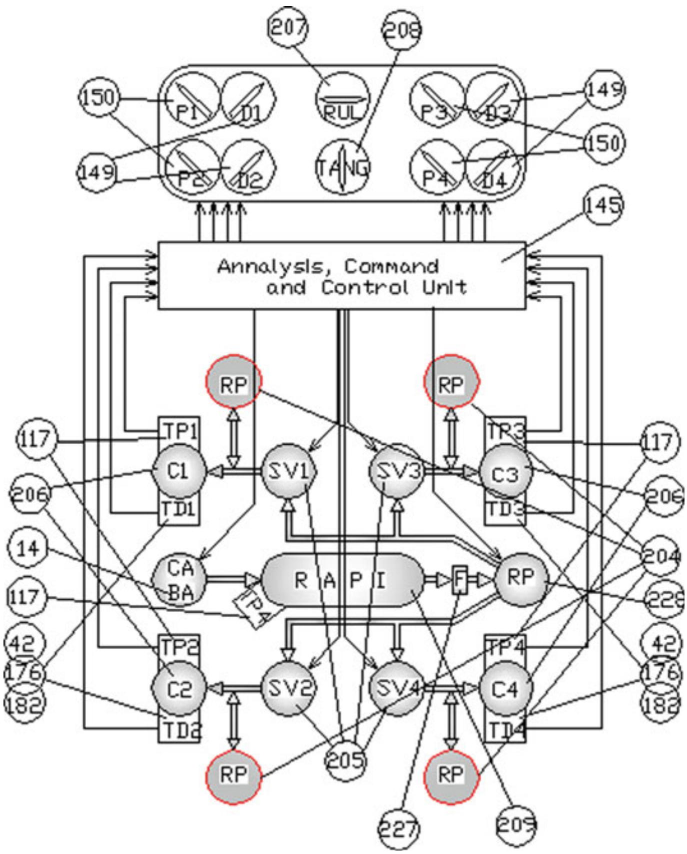


Fig. 3 The block diagram for step by step or in real time vehicle trim control

The Quarter Car Model Realized in Adams-View Module

The quarter car model realized with ADAMS, module View is presented in the Fig. 5.

The damping characteristic is defined by damping forces at different speed for each strokes respectively one for rebound and other for compression.

The contact force road-wheel (CONTACT_1) is defined based on the tire rigidity.

The stopper buffer forces on compression (CONTACT_2) and rebound (CONTACT_3) are defined based on the each specific rigidity characteristics.

The road excitation is realized with a function generator.

The software allow the model evolution visualisation in real time, also generating the diagrams of displacements, forces, accelerations, speeds, for each elements or for relative evolution between diverse elements.

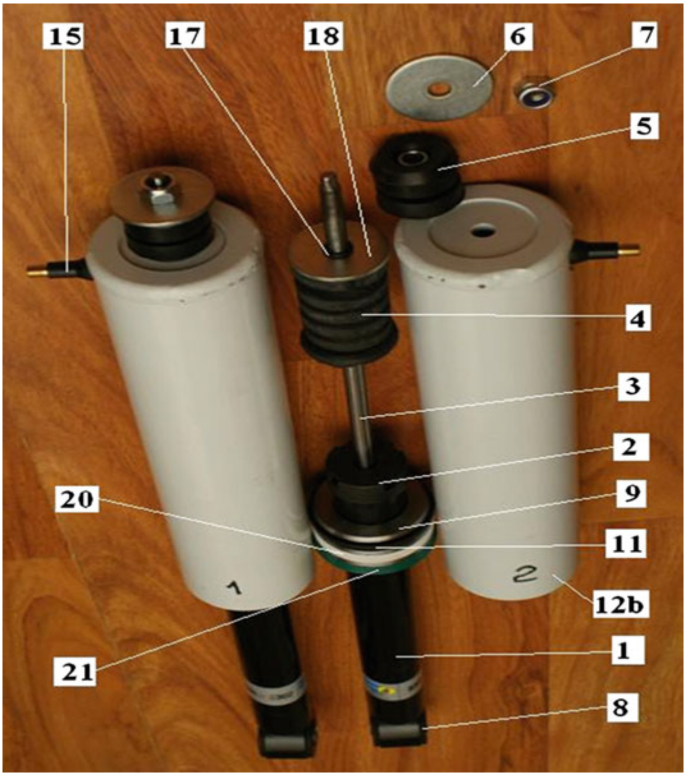


Fig. 4 The realized trim corrector devices

The elements are:

1	Vehicle body
2	Translational joint for sprung mass
3	Integrated spring-damper
4	Main suspension spring
5	Compression stopper buffer
6	Axle
7	Translational joint for axle
8	Rebound stopper buffer
9	Road
10	Translational joint for road
11	Under body bottom level

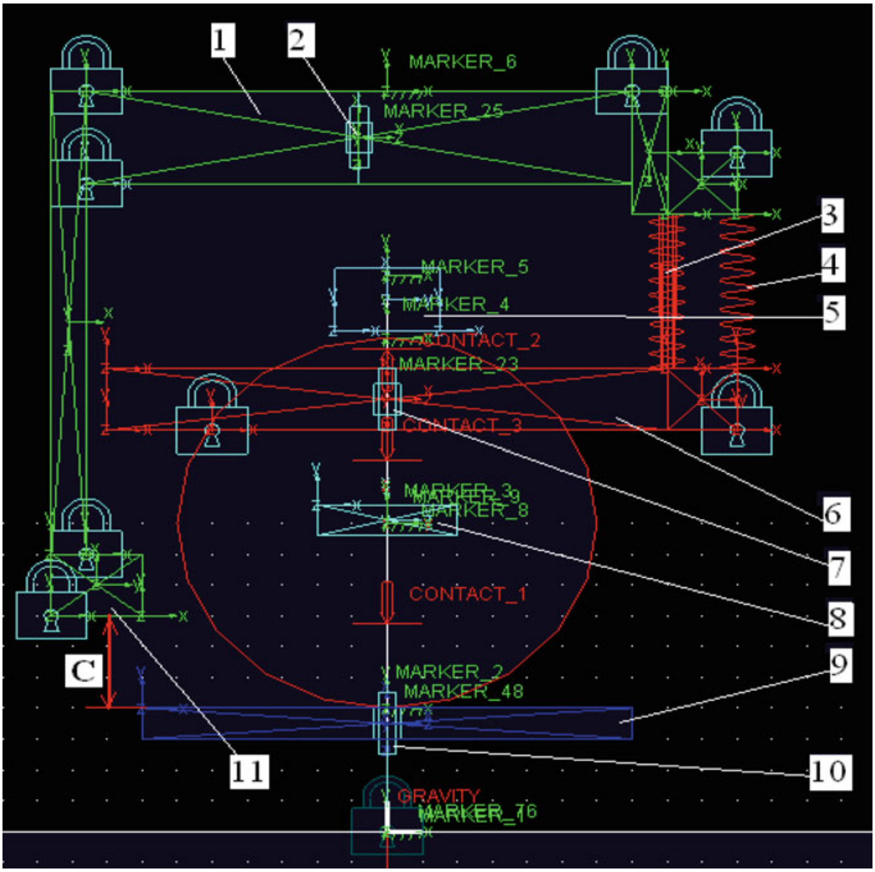


Fig. 5 The quarter car model with integrated spring-damper and standard spring

In the figure the padlocks represents the fixed joints linking the elements belongs to the each parts.

C—body-ground clearance.

The model covers both solutions, respectively solution:

- with two springs e.g. mains suspension spring (4) and correction spring included in integrated spring-damper (3);
- with one spring e.g. only spring included in integrated spring-damper (3), this spring taking the role of the main suspension spring, but being adjustable, situation in which the spring (4) has null rigidity.

Table 2 The springs forces and lengths used for trim corrector efficiency evaluation

Loaded state	Sprung mass [kg]	Sprung weight [N]	Trim correction value [m]	Spring force [N]	Spring length [m]	
					Normal position	Corrected
Fully	360	3530	0.00	3530	0.2265	–
Fully	360	3530	0.04175	3530		0.26825
Fully	360	3530	0.06	3530		0.2865

The Tested Corrections

The springs forces and lengths used for trim corrector evaluation are presented in the Table 2.

Numerical Application

The road/car vertical interaction has been simulated using ADAMS software View module.

The considered car has the following characteristics:

$m_U = 240\,[\mathrm{kg}]$	sprung mass at unloaded
$m_F = 360\,[\mathrm{kg}]$	sprung mass at fully loaded
$m_{US} = 35\,[\mathrm{kg}]$	unsprung mass
$l = 0.236\,[\mathrm{m}]$	the overall suspension stroke
$d_{RB} = 0.014\,[\mathrm{m}]$	the rebound stopper buffer deformation, under 5000 [N]
$d_{CB} = 0.040\,[\mathrm{m}]$	the compression stopper buffer deformation, under 1000 daN
$k_1 = 14085\,[\mathrm{N/m}]$	the suspension rigidity
$k_T = 2.1810^8\,[\mathrm{N/m}]$	the maximal tire rigidity at the deformation of 0.06 [m]
$k_2 = 14085\,[\mathrm{N/m}]$	the trim corrector rigidity (took identically with main spring)
$k_{CB} = 245166\,[\mathrm{N/m}]$	the compression stopper buffer rigidity
$k_{TD} = 350237\,[\mathrm{N/m}]$	the rebound stopper buffer rigidity
$\delta_{U-F} = 0.0835\,[\mathrm{m}]$	the suspension stroke between unloaded to fully loaded state

$$\delta_{U-F} = \frac{G_F - G_U}{k_S} = \frac{(360 - 240) \cdot 9.80665}{14085} = 0.0835\,[\mathrm{m}] \tag{1}$$

Test Conditions

The simulation was realized for fully loaded car using a road generated by a sum of harmonic functions presented in Eq. (2).

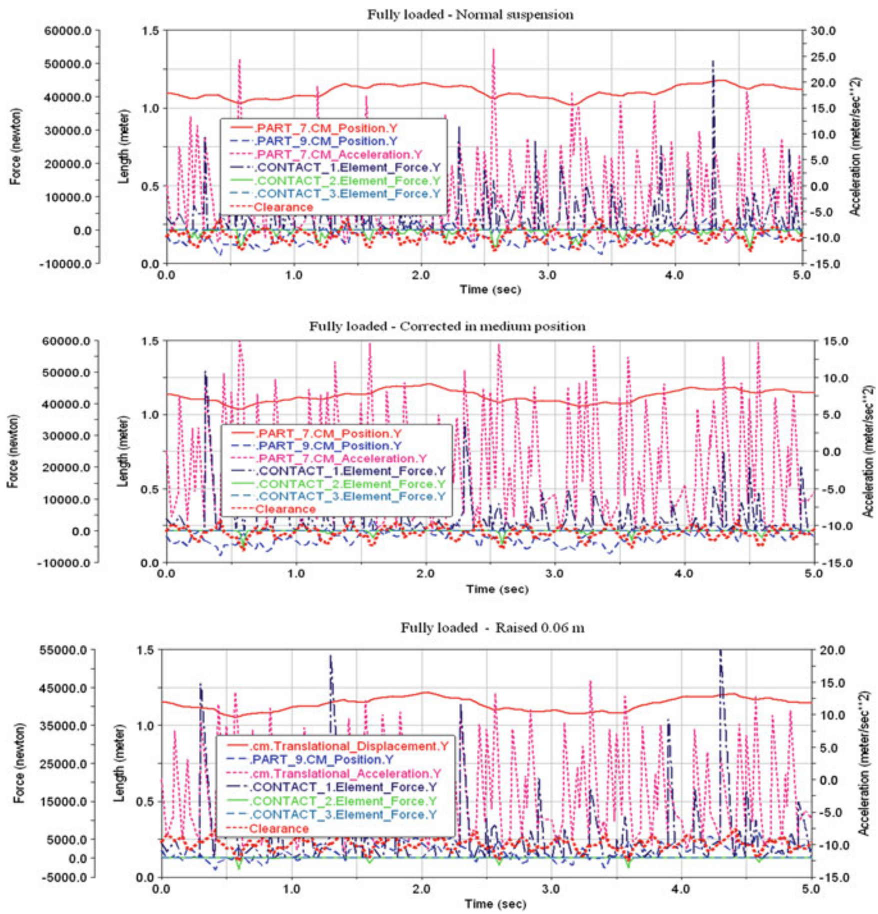
The excitation covers the specific frequencies area, being under the body frequencies up to the wheel proper frequencies.

$$h = 0.05\ \sin(2\pi \cdot 0.4 \cdot t) + 0.04\ \sin(2\pi \cdot 3 \cdot t) + 0.03\ \sin(2\pi \cdot 8 \cdot t) + 0.02\ \sin(2\pi \cdot 15 \cdot t) \quad (2)$$

Results

The simulation were realized for the suspension no trim corrector action and with trim corrector lifting the car body 0.04175 [m] (representing medium stroke position) and 0.06 [m], the result being presented in the Table 3.

Table 3 The simulation results



The parameters for behavior evaluation are:

- Body-road clearance, evaluated by RMS and minimal values
- Comfort, evaluated by RMS and maximal car body vertical accelerations;
- Adherence, evaluated by wheel-road RMS contact force;
- Body and axles protection, evaluated by RMS and maximal buffer strike force

Where: RMS—root mean square
In the diagrams:

- PART_7.CM_Position.Y—represents the vertical body position
- PART_7.CM_Acceleration.Y—represents the vertical body acceleration
- PART_9.CM_Position.Y—represents the longitudinal road profile
- (CONTACT_1), (CONTACT_2) and (CONTACT_3) were defined previous

In the Table 4 are presented the performances improvement, due to the trim corrector action.

The evaluation is realized comparing each result with value corresponding situation without trim corrector.

Table 4 The performances improvement, due to the trim corrector action

Fully loaded						
Parameter		Normal position	Raised in medium position		Raised 0.06 m	
		Values	Values	Improvement (%)	Values	Improvement (%)
Body-ground clearance [m]	RMS	0.179	0.204	14	0.219	22.32
	Minimal	0.079	0.082	4.4	0.106	34.39
Vertical body acceleration [m/s^2]	RMS	8.444	7.781	7.85	7.743	8.31
	Maximal	26.342	14.939	43.3	15.149	42.49
Adherence [N]	RMS	8927.932	7303.795	−18.19	10235.58	14.65
Force in compression buffer [N]	RMS	1401.342	745.963	46.77	0	100
	Maximal	5666.359	5139.972	9.29	2941.499	48.1

Conclusions

The simulations confirm the trim corrector increases the suspension performances, thus for the analyzed case the trim corrector increase simultaneous:

• Body-ground clearance	—evaluated by RMS values	between 14 ÷ 22.3 %
	—evaluated by minimal value	between 4.4 ÷ 34.4 %
• Body comfort	—evaluated by RMS values	between 7.9 ÷ 8.3 %
	—evaluated by maximal body acceleration	between 43.3 ÷ 42.5 %
• Adherence	—evaluated by RMS wheel-ground contact force	between −18.2 ÷ 14.7 %
• Body/axles protection	—evaluated by RMS buffer force	between 46.8 ÷ 100 %
	—evaluated by maximal buffer force	between 9.3 ÷ 48.1 %

The novel trim corrector solutions can be applied even on the Macpherson variants improving performances on all variants by trim correction step by step or for better behavior in real time trim control.

On good roads, by reducing body-ground clearance, decreases pitch and roll axes and thus increasing stability at pitch and roll, increasing stability and cruise speed.

On bed roads, by increasing body-ground clearance, increasing passing capacity and body protection.

Reference

ADAMS Handbook