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ADVANTAGES CONFERRED BY SHOCK ABSORBERS WITH CYLINDRICAL ACTUATOR APPLICATION TO LANDING GEAR

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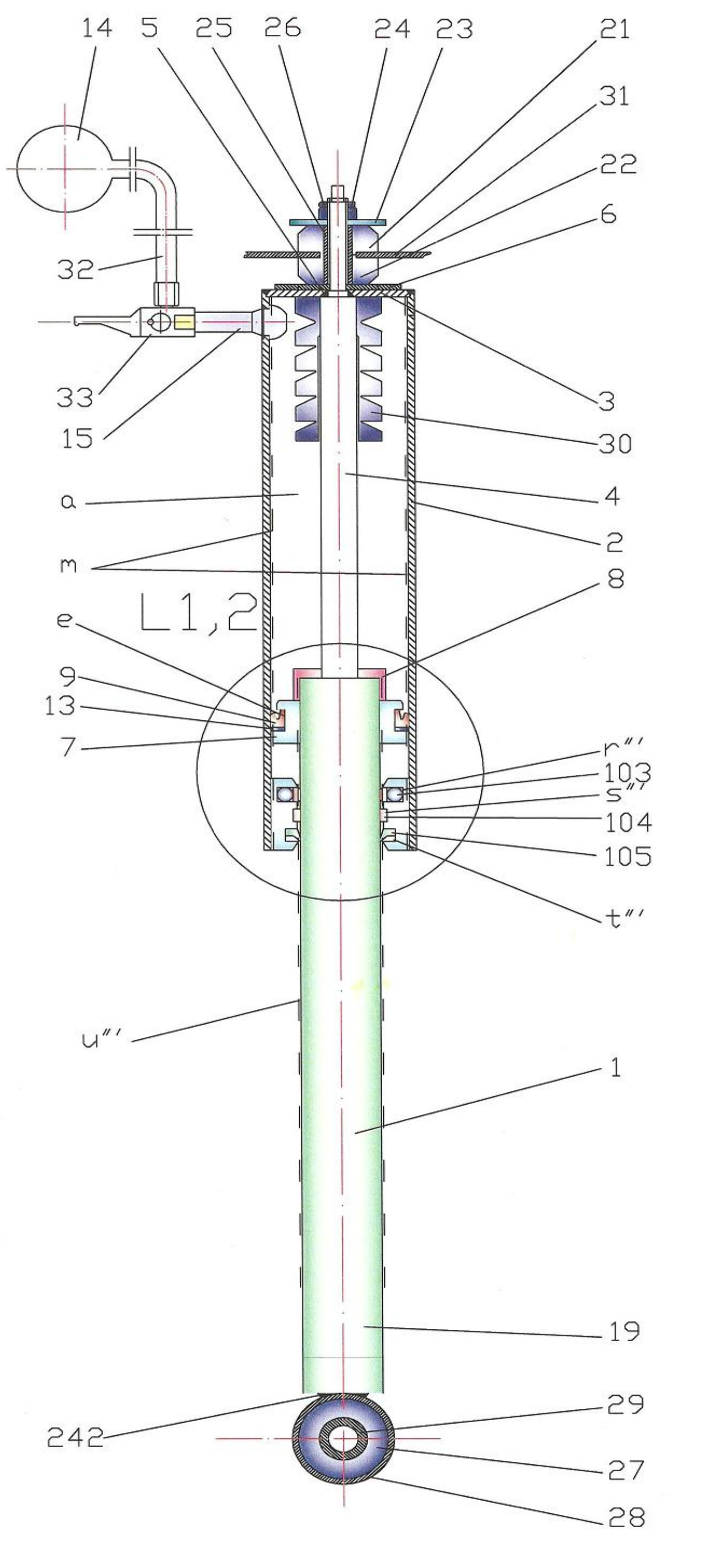
Abstract

Shock absorber with cylindrical actuator is a new concept of integrated damper with floating device, in international patent application PCT/EP2016/061515, with wide application in road, rail and aerial vehicles. Comparative to the known solution with rubber sleeves or bellows, the new one is capable to work at more increased pressure being more compact and due to metallic cylinder is more reliable. The other important advantage consists of it applicability at any kind of shock absorber without any special preparation, the solution consisting of replacing the dust shield with a pneumatic cylinder sealed against rod with a gasket and sliding closed in the lower part by sealing element/s fitted in trough/troughs practiced in an annular body fastened against the outer cylinder. For a better behaviour the patent application contains and solutions with double sliding sealing working at high pressure and thus assuring enough floating forces to sustain the vehicle without standard metallic spring so it can be utilized successfully in aerial vehicles landing gear. By using displacement and pressure transducers and equipment of control and command, it becomes an active suspension. The paper presents the double sliding sealing solution and demonstrates, by simulation the advantages confer by this new solution of shock absorber with cylindrical actuator in landing gear. This purpose was realized a virtual suspension model on which simulated hard landing for vehicle load and unload states, for different pneumatic spring preloaded forces.

Keywords: *shock absorber, cylindrical actuator, simulation, comfort, load state, vehicle protection, pneumatic spring*

1. Introduction

The patent application has solutions for single and double sliding sealing, the first or second version being adopted function the working conditions. In Fig. 1 is presented version with double sliding sealing.



No.	Element
1	Shock absorber
2	Pneumatic cylinder
3	Cylinder lid
4	Rod
5	Gasket
6	Washer
7	Annular body
8	Bump cup
9	Seal element
10	High speed seal member
11	Guiding ring
12	Wiping element
13	Pusher ring
14	Compressed gas/air source
18	Upper clamp
19	Outer cylinder
21	Upper gripping pad
22	Lower gripping pad
23	Washer
24	Locking nut
25	Spacer hub
26	Nut and jam nut
27	Bushing
28	Outer hub
29	Inner hub
32	Hose
33	Quick plug
101	Annular body
102	Seal element
103	High speed seal element
104	Guiding ring
105	Wiper element
242	Weld cord
a	Toric chamber
e	Circular trough
m	Inner sealing surface
r’’’	Circular trough for 103 seal
s’’’	Circular trough for 104 ring
t’’’	Circular trough for 105 wiper
u’’’	Outer sealing surface

Fig. 1. Shock absorber with cylindrical actuator – version double sliding sealing [1]

The novelty is to create a controllable buoyant force under the damper dust shield, by replacing it with a pneumatic cylinder and sliding closing the area between it 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.

The proposed trim corrector may be applied on any kind of new or worn shock absorber/ strut, having applicability on each vehicle kind including motorcycles, cars, buses, trucks, trains, military and racing vehicles, improving performances, comfort and active and passive safety.

The proposed actuators cost is less than $200/2 pieces comparative with the known solution realized with sleeve/bellows costing $ 1000/2 pieces.

The double sliding sealing permit increased working pressure, thus it can be used in plain landing gear, having important advantages conferred by possibility to easy adjust the buoyant force.

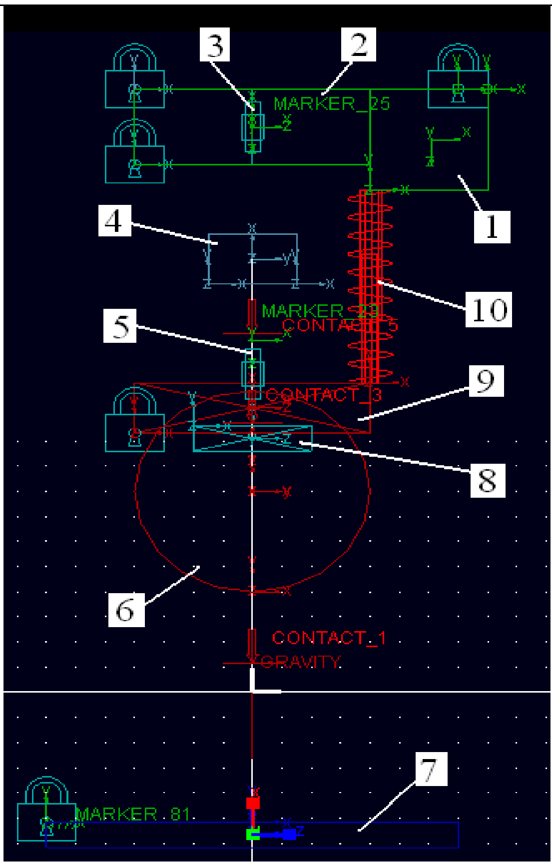
The next simulations will demonstrate the advantages of buoyant force adjusting according to the vehicle weight state, which has important variation between unloaded and fully loaded situation.

2. Simulations for evaluation optimal bearing force function vehicle load state

The evaluation of optimal bearing force function vehicle load state is realised at hard condition where this is more evident, so will realise for vehicle brutal landing.

2.1. The vertical crash simulation model

The virtual model was realized with ADAMS View software and is presented in Fig. 1.



The component elements are:

1. sprung vehicle mass
2. sprung payload
3. translational joint of sprung mass
4. compression stopper bumper
5. translational joint of axle
6. wheel with tire
7. landing runway
8. rebound stopper bumper
9. axle
10. integrated shock absorber-pneumatic spring

The padlocks represent fixed joints used to stiffening different parts, respectively:

- Element 1 with elements 2, 4, 8
- Element 6 with element 9
- Element 7 with ground

The contact forces are:

Contact 1: Force between tire and ground

Contact 2: Force in rebound stopper bumper

Contact 3: Force in compression stopper bumper

Fig. 2. The vertical crash model

The force of pneumatic spring vary according to relation (1)

$$F_P = F_0 + k_P \bullet \delta, \tag{1}$$

where:

F_P – pneumatic force,
F_0 – pneumatic force at the suspension maximum détente,
k_P – pneumatic suspension rigidity,
δ – suspension elongation.

2.2. Test conditions

The tests will be realised for brutal landing with the vehicle minimal loaded and fully loaded, for some pneumatic spring characteristics.

The normal landing is considered when the vertical speed is less than 2 m/s [2], so for brutal landing will utilise a descending speed of 3 m/s, speed realised by dropping from a height calculating below:

$$h = \frac{v^2}{2g} = \frac{3^2}{2 \bullet 9.81} = 0.4587\ [m], \tag{2}$$

where:

h – drop height,
v – speed crash,
g – gravitational acceleration.

2.3. Numerical application

The vertical interaction has been simulated using ADAMS software View module.
The characteristics of the considered model of suspension are presented in Table 1.

Tab. 1. Suspension characteristics

Symbol	Value	Units	Parameter
m_{S0}	240	[kg]	sprung mass at Minimal loaded (noted Unload)
m_{SF}	360	[kg]	sprung mass at Fully loaded
m_U	35	[kg]	unsprung mass
m_{T0}	275	[kg]	total mass at Minimal loaded
m_{TF}	395	[kg]	total mass at Fully loaded
l	0.236	[m]	overall suspension stroke
k_P	14085	[N/m]	pneumatic suspension rigidity
k_T	120000	[N/m]	tire rigidity
k_{CB}	380000	[N/m]	compression stopper buffer rigidity
k_{RB}	580000	[N/m]	rebound stopper buffer rigidity

The used damping characteristic is presented in Tab. 2.

Tab. 2. Shock absorber damping characteristic

Speed [m/s]		0.05	0.1	0.2	0.3	0.4	0.55	0.75	0.95	1.5	3
Force [N]	Rebound	70	170	410	650	800	1030	1320	1600	2450	4600
	Compression	170	210	320	440	530	650	830	1000	1500	2740

2.4 Results

The suspension quality will be evaluated by the body deceleration and by the forces in tire and in rebound and compression stopper bumpers.

The vehicle body acceleration is a criterion for passenger security and the forces in tire and in stoppers bumpers are criteria for vehicle and landing runway protection.

In the Tab. 3 are presented the maximal and RMS values resulted during the simulations.

Tab. 3. Simulation results

Preload [N]	Load state	Case	Acceleration [m/s²]		Tire Force [N]		Rebound Bumper Force [N]		Compression Bumper Force [N]	
			Max	RMS	Max	RMS	Max	RMS	Max	RMS
9875	Load	1	26.10	10.11	46652	6178	14233	7122	0	0
	Unload	2	41.36	12.91	29187	4635	12853	7805	0	0
8875	Load	3	23.75	9.80	22742	5424	13738	6294	0	0
	Unload	4	37.61	11.97	17863	4300	12395	6930	0	0
7875	Load	5	21.68	8.98	24660	5358	11530	5270	0	0
	Unload	6	33.97	11.37	18405	4094	12779	5984	0	0
6875	Load	7	24.15	8.66	39891	5612	11738	4415	2107	207
	Unload	8	30.48	10.50	31355	4334	10874	4993	0	0
5875	Load	9	35.87	8.22	16789	4834	9368	3503	6846	756
	Unload	10	27.23	9.79	18688	3797	10959	4091	0	0
4875	Load	11	45.83	9.66	20390	5420	7919	3622	11388	1750
	Unload	12	24.26	8.96	18539	3594	8684	3216	0	0
3875	Load	13	57.89	10.62	24765	5692	6536	1831	16740	2507
	Unload	14	22.39	7.83	17836	3468	7744	2258	667	61
2875	Load	15	69.96	10.28	29139	5535	5571	1325	5571	1325
	Unload	16	39.43	7.81	17324	3409	4481	1454	5420	559
1875	Load	17	79.42	12.85	32549	6248	4173	833	26458	3914
	Unload	18	54.07	8.63	15692	3509	4173	828	10003	1250

In Fig. 3 are presented the diagrams realised for Cases 1 and 2, 9 and 10 and 17 and 18.

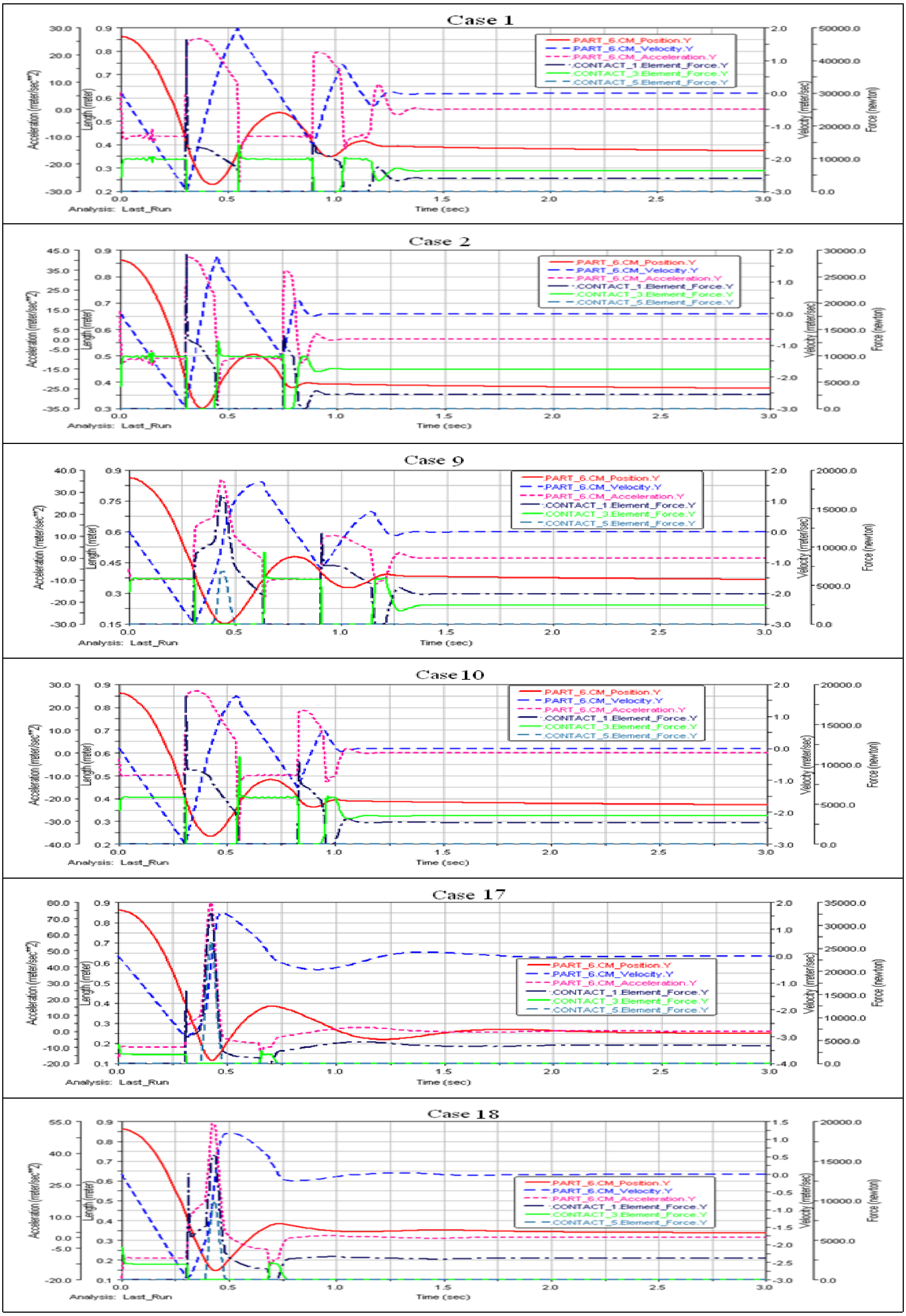
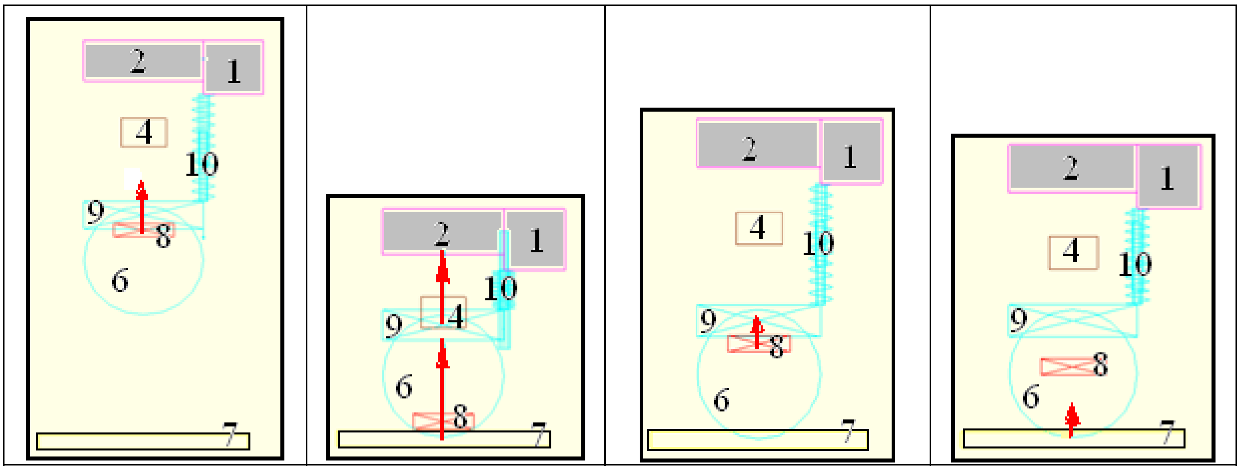


Fig. 3. The diagrams realised for Cases 1 and 2, 9 and 10 and 17 and 18

In Fig. 3 were presented the diagrams for extremes and middle values, of the pneumatic spring preloaded, to highlight its influence in suspension behaviour.

The proposed dynamic model reproduced the real behaviour presenting the movie of all events, in Fig. 4 being presented the main moments.



Dropping from “*h*” altitude	Collision with the runway and compression bumper	Oscillations between the compression and rebound bumpers	Stabilisation

Fig. 4. The main moments in crash

The elements numbered in Fig. 4 have the signification from main model presented in Fig. 2 and explained in Tab. 2.

3. Result analysis

The passenger comfort is evaluated based the minimal sprung mass deceleration and vehicle protection by the minimal values of the forces in tire and rebound and compression bumpers, these values being presented in Tab. 4.

Tab. 4. *Minimal values of the forces in tire and rebound, and compression bumpers*

Criteria	Element	Parameters	Vehicle loaded state	
		Lowest values	Minimal/Case	Fully/Case
Comfort	Sprung mass	Acceleration [m/s²]	22.39 Case 14	21.68 Case 5
Vehicle protection	Tire	Force [N]	15692 Case 18	16789 Case 9
	Rebound bumper	Force [N]	4173 Case 18	4173 Case 17
	Compression bumper	Force [N]	<100000 Cases 2. 4, 6, 8, 10, 12, 14, 16, 18	<100000 Cases 1. 3, 5, 7, 9, 15

Tab. 4 shows different spring values for comfort and vehicle protection better behaviour, so for a global evaluation will analyse the diagrams from Fig. 5 realised based values from Tab. 3.

Fig. 5 presents the diagrams for evolution of the maximal values of vehicle body acceleration and of the forces in tire contact with the runway and in rebound and compression bumpers.

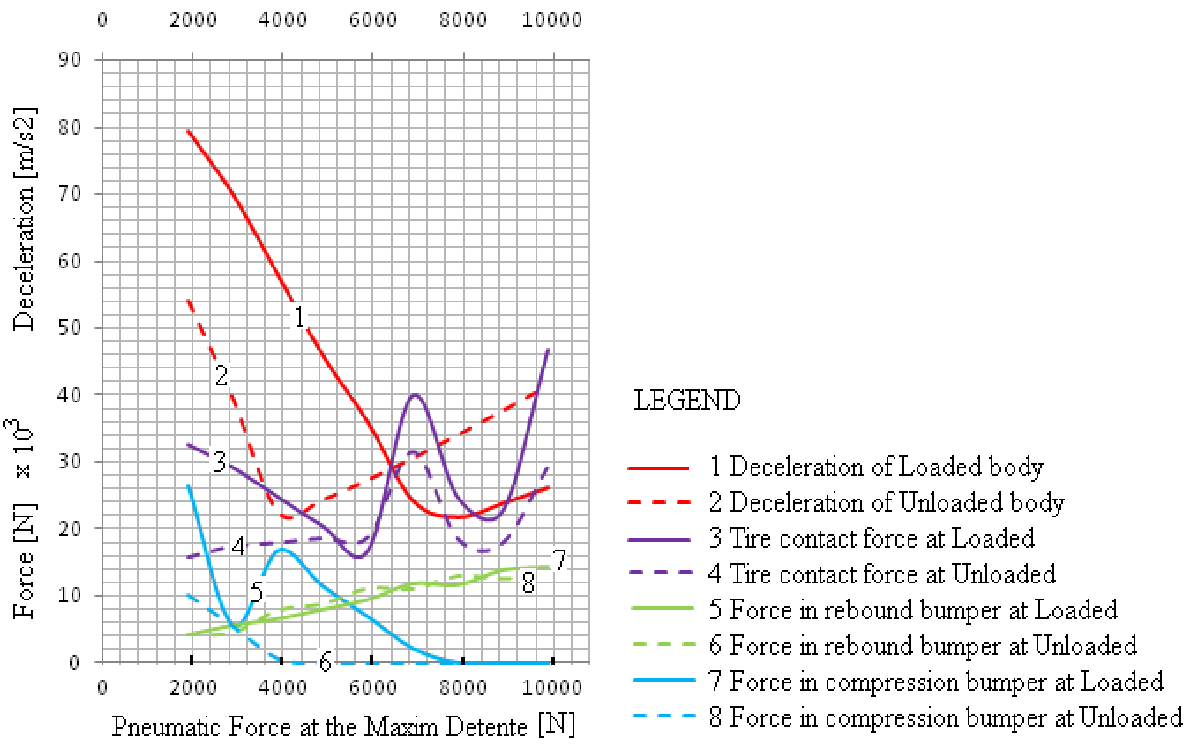


Fig. 5. Evolution of the vehicle body deceleration and of the forces in tire and in rebound and compression suspension stopper bumpers

Based Fig. 5 we can conclude globally better behaviour is obtained:

- for fully load vehicle at spring preloaded values 8000÷9000 N,
- for vehicle minimal loaded at spring preloaded values 3600÷4400 N.

4. Conclusions

The main purpose of the paper was to demonstrate the vehicle load state influence in passengers comfort and in body and axle mechanical loads.

Obviously suspension parameters optimisation will improve it performances, but the used model marked big behaviour differences between loaded and unloaded vehicle state, at the same others conditions, so evidencing the advantages conferred by according the spring characteristic with the vehicle load state.

The solution of shock absorber with adjustable pneumatic actuator, protected by patent application nominee in [1] with a variant presented in Fig. 1, can solve the problem to adjust properly the pneumatic spring characteristic.

The solution of shock absorber with adjustable pneumatic actuator according [1] has the same application in road and rail vehicles suspensions, e.g. paper [3].

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[3] Wikipedia, *Hard landing,* https://en.wikipedia.org/wiki/Hard_landing.