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EVALUATION OF DISSIPATED ENERGY BY THE CAR DAMPERS

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Scientific coordinator *:*
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Valencia, 2015

SUMMARY

1. Actual situation of fuel consumption reduction

Achievements in the field of energy recovery

I. Thermal engines modifications

- direct injection: 8% - 20%
- variable compression ratio & downsizing : 8% - 30%
- multi valve engine: 5% - 10%
- variable valve timing : 5% - 8%
- cylinder suspending: 5% - 15%
- Reconception the combustion chamber, limiting the compression ratio, injectors control, the mixture formation and combustion

II. Optimisation the aerodynamics

- fuel consumption economy : 5%
- modiffication the habitacle
- modification the car design

III. Automated transmissions and hybrid traction

- fuel consumption economy (NEDC cycle): 15%
- price
  internal management of available energy
  optimisation the recovery of braking energy

IV. Reduce rolling resistance tyres

- fuel consumption economy : 6%
- modification the conduit car

V. Car weight reduced

- fuel consumption economy (NEDC cycle): 2% - 9%
- subcomponents car price: 50% - 130%

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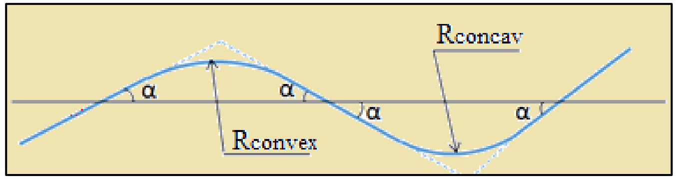
2.1 Road profile

Road macrostructure

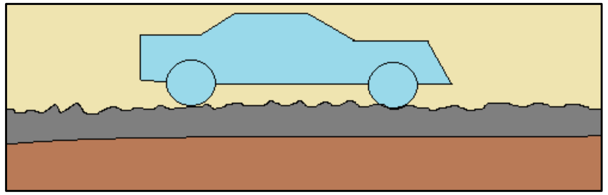
Road microstructure



8 macrostructural road profiles with maximum speed between 25Km/h – 120Km/h

27 road profiles

120 Km/h	X			
100 Km/h	X	X		
80 Km/h	X	X	X	X
60 Km/h	X	X	X	X
50 Km/h	X	X	X	X
40 Km/h	X	X	X	X
30 Km/h	X	X	X	X
25 Km/h	X	X	X	X
	ISO A-B	ISO B-C	ISO C-D	ISO D-E



4 microstructural road profiles

ISO A-B (Δh = ± 15 mm)

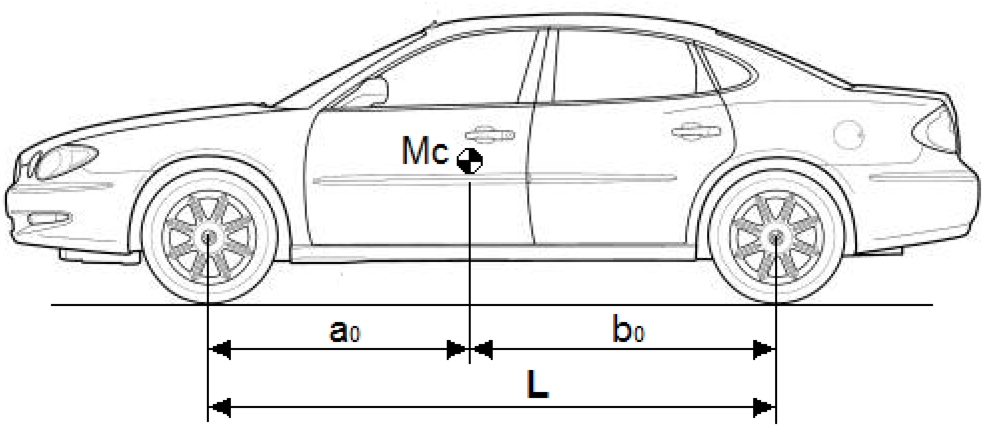
ISO B-C (Δh = ± 25 mm)

ISO C-D (Δh = ± 50 mm)

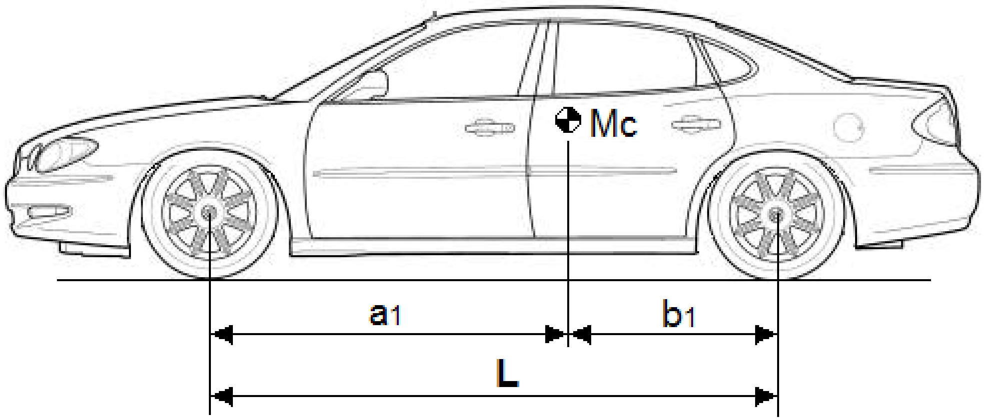
ISO D-E (Δh = ± 100 mm)

2.2 Car parameters

Parameters used in the car simulation have been chosen as the average values of middle-class cars, in two situations:



unladed weight: $m_0 = 1100$ kg
wheelbase: $L = 2600$ mm
the ratio: $a_0 / L = 0.45$
the ratio: $b_0 / L = 0.55$



total weight $m_1 = 1600$ kg
wheelbase $L = 2600$ mm
the ratio $a_1 / L = 0.55$
the ratio $b_1 / L = 0.45$

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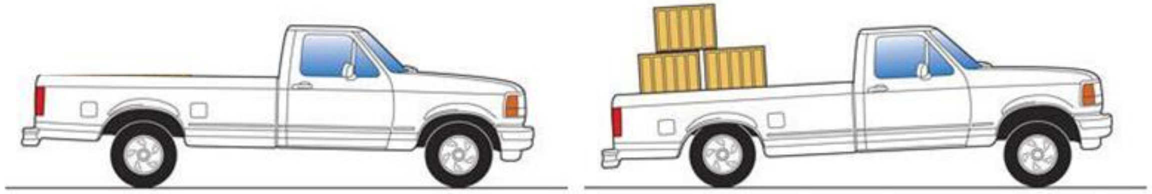
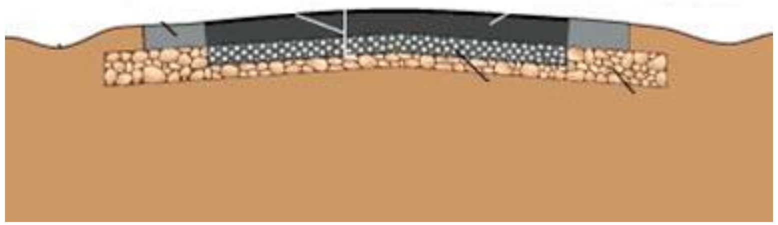
2.3 The simulation conditions

- simulation performed in two conditions, the car's unladed weight and with total weight

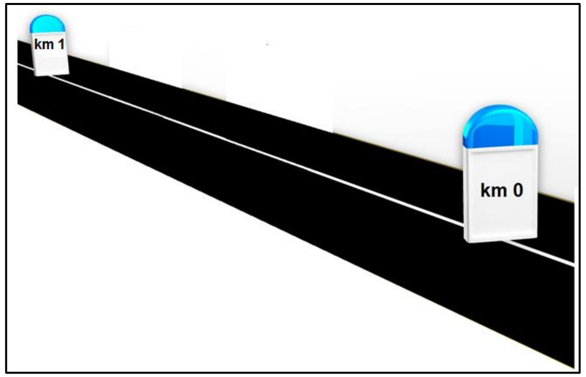


- straight displacement at a constant speed

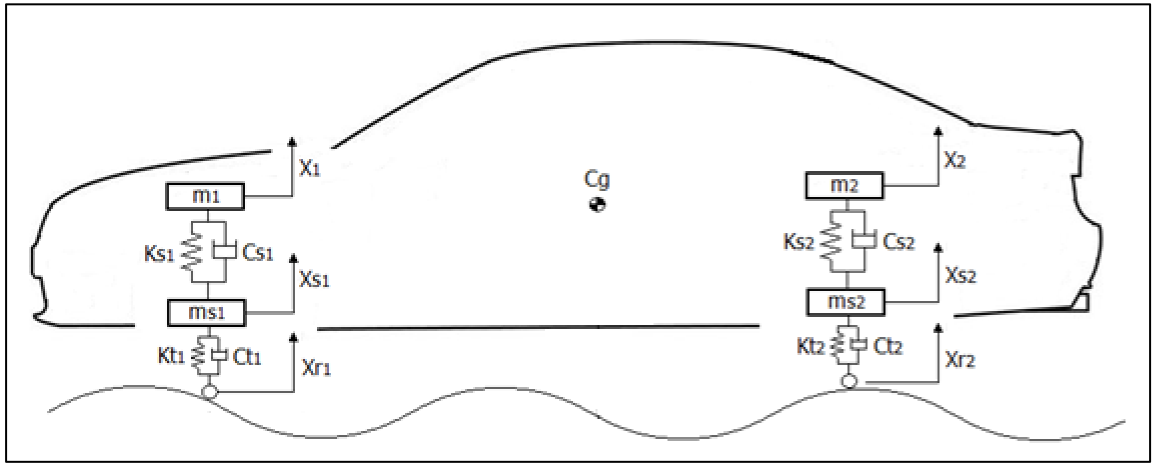
- the cross profile of the lane road is symmetrical

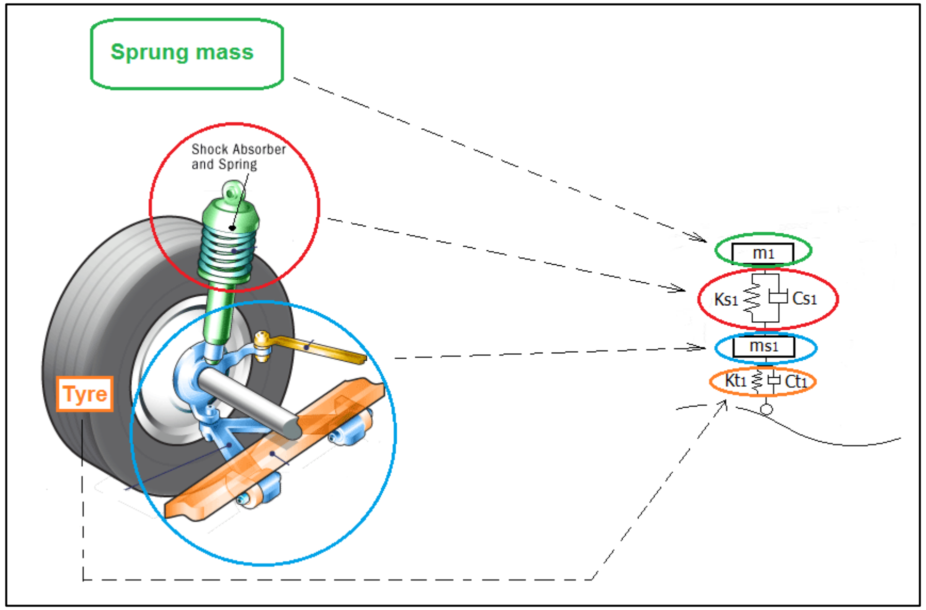


- all the road profiles used in simulation have a length of 1 km



3. Mathematical model





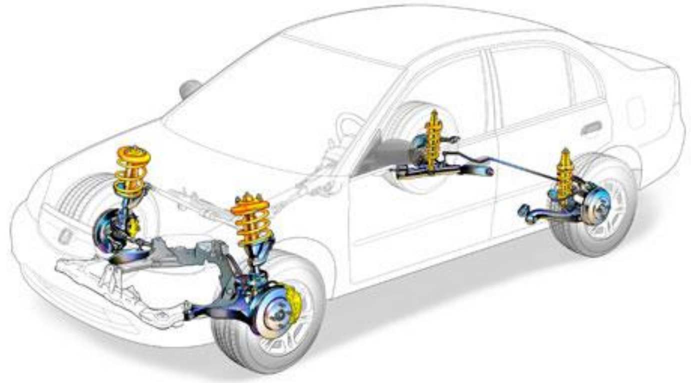
The suspension itself includes:

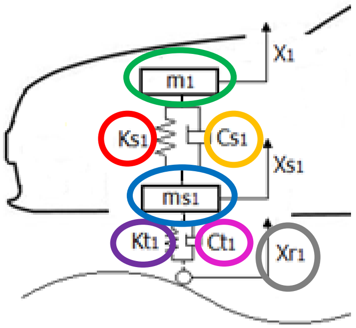
- the spring *(ks)*
- the damper *(cs)*
- the sprung mass *(m)*

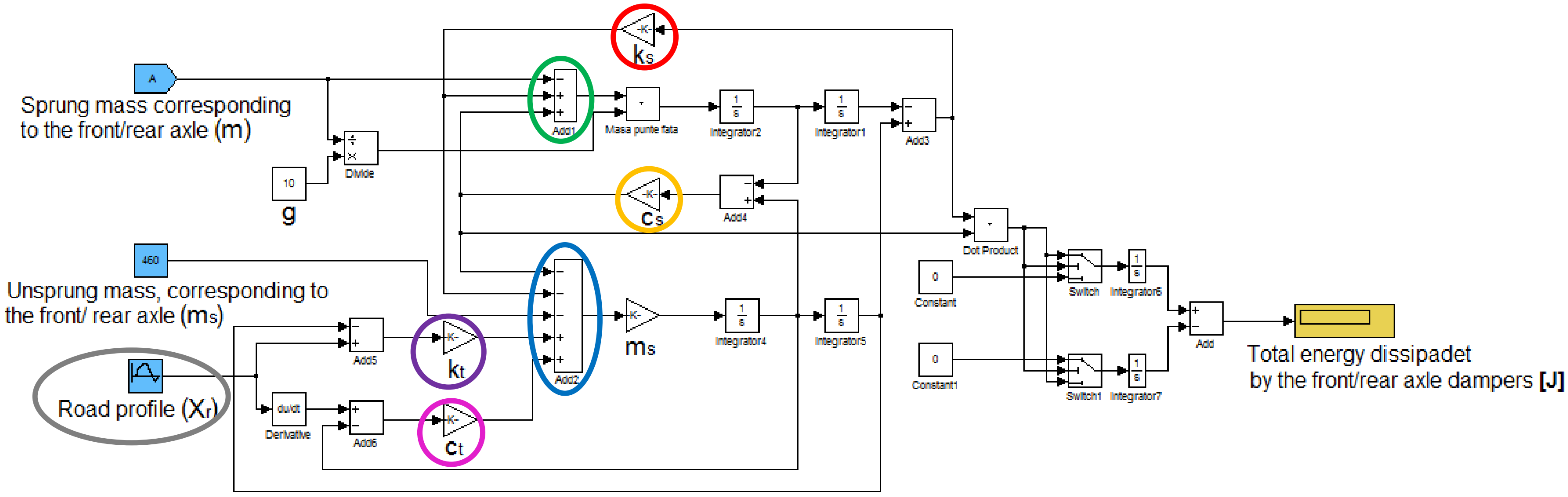
The tire was defined as an independent suspension with the same elements

- the spring *(kt)*
- the damper *(ct)*
- the unsprung mass *(m)*

4. Simulink model







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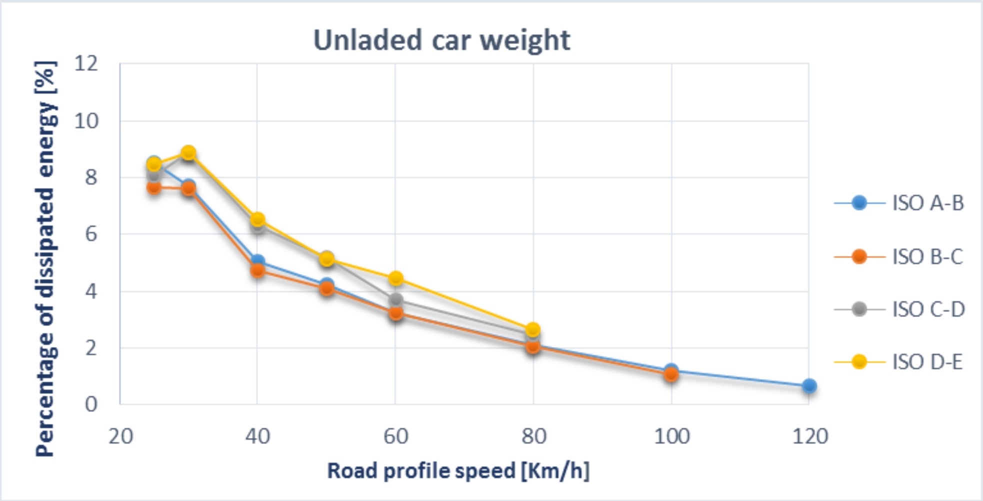
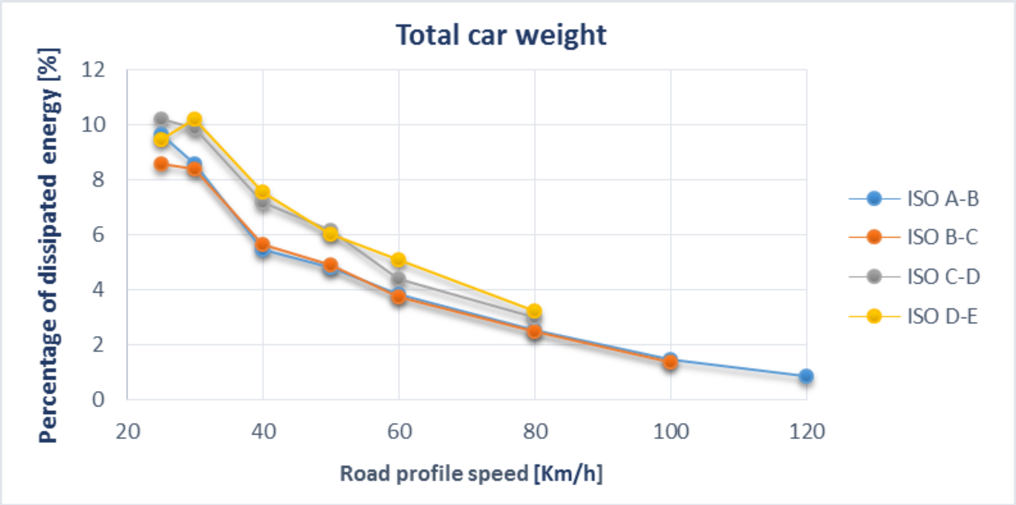
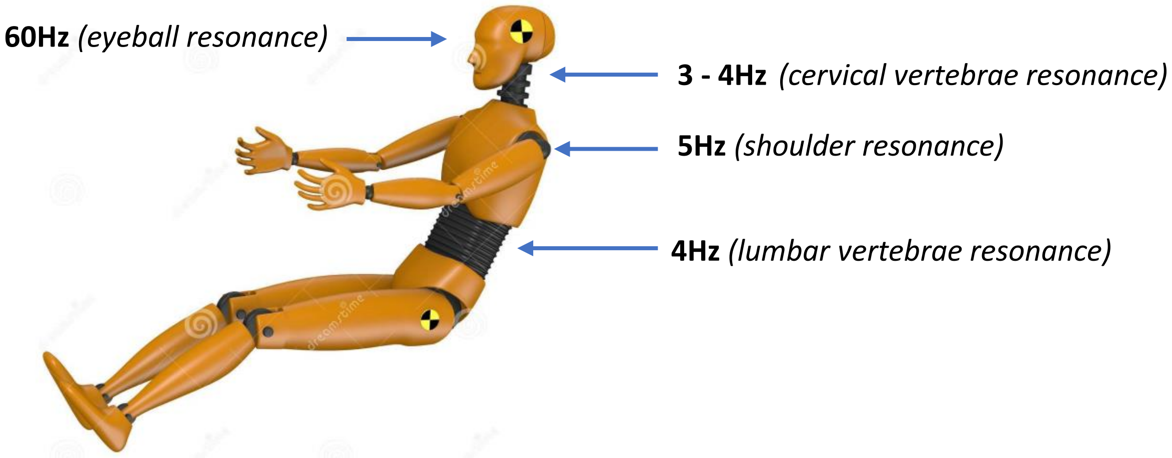
5. Results

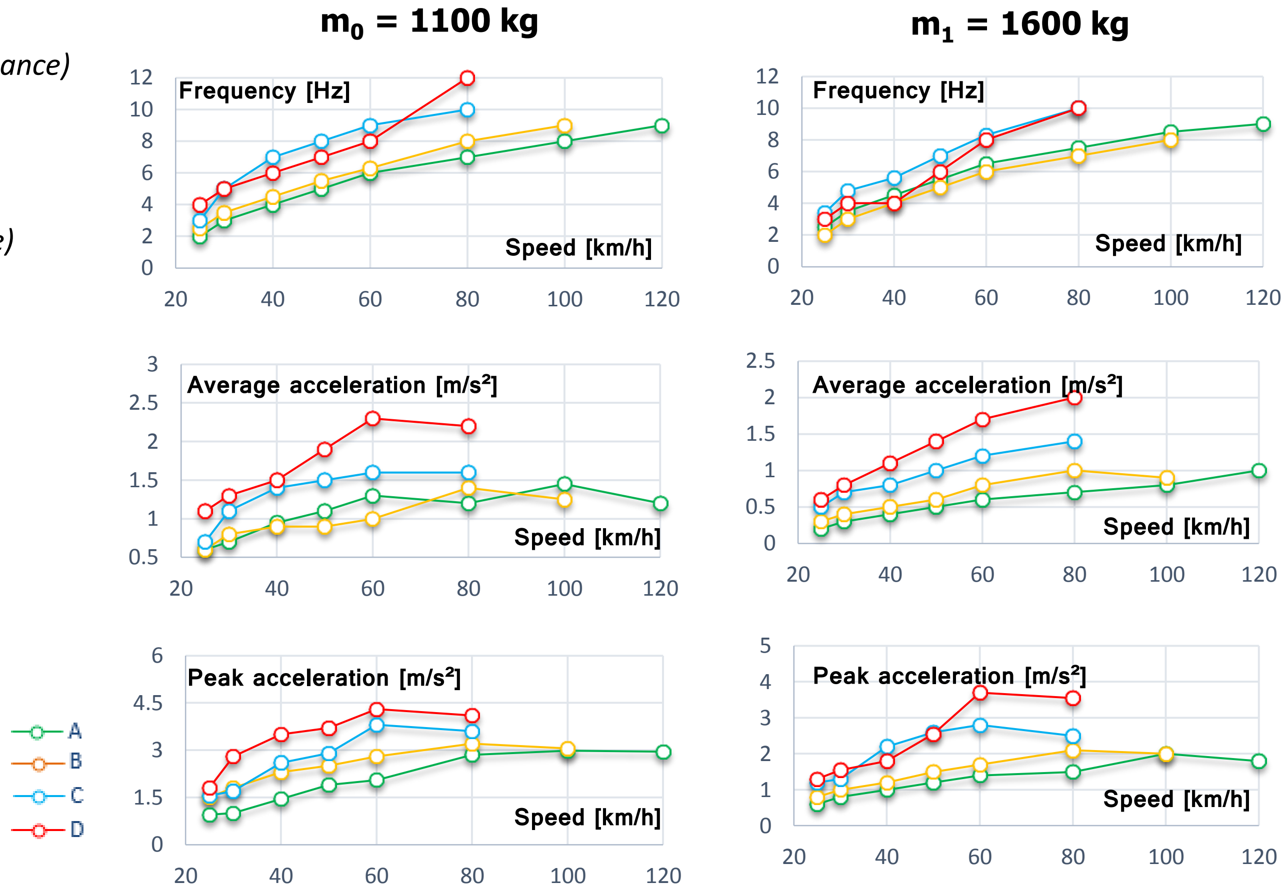




Percentage of energy dissipated by the dampers, in relation to the energy consumed by the engine car with unladed/ total weight, to cover the distance of 1 km
(the car has tires rolling resistance coefficient f = 0.008, the drag coefficient c_x = 0.28 and the frontal area A_x = 2 m^2)

6. Vehicle vibration effects on the human body





Fluctuation of acceleration effects on human body

Oscillation frequency [Hz]	Human sense that depends on oscillation acceleration [m/s²]	
	unpleasant	painful
60	2.3	2.7
90	2.1	2.5
120	1.9	2.3
180	1.7	2.0

7. Conclusions

- the simulation of system suspension shows a relation between the energy dissipated by the damping car and vehicle and road profile properties.

- among the properties of the car, it results that the mass of the car (m), the suspension spring (k_s) and the suspension damping (c_s) contribute most to the percentage of energy dissipation. An increase of mass vehicle and damping coefficient, corroborated with a decrease of spring rate, will produce a higher energy dissipation for the dampers.

- the road profile subcomponent who have the biggest influence on the suspension excitation is the microstructure. The macrostructure has an important role only if the road profile speeds is below 60 km/h.

- the macrostructure profiles of road categories with maximum speeds between 25 km/h - 60 km/h and microstructures profiles of road categories ISO C-D and ISO D-E contributes to increased suspension load.

Thank you for your attention !

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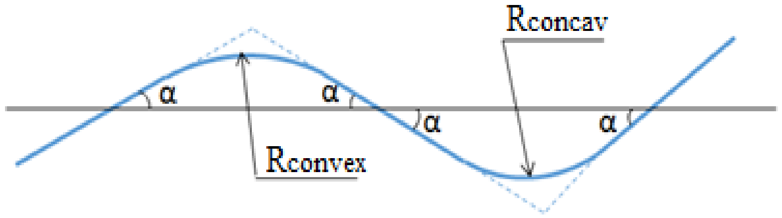
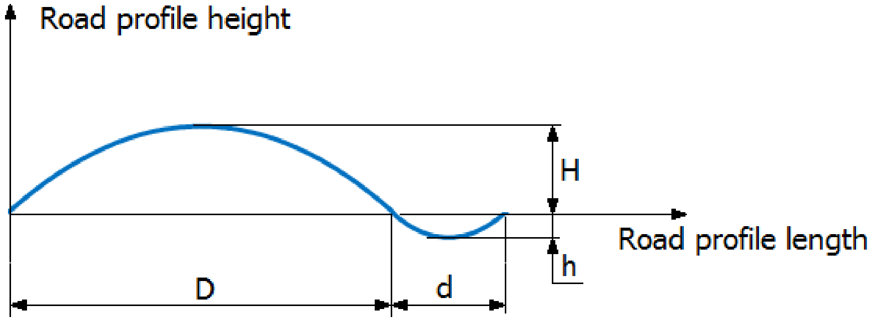
Annex 1 **:** Macrostructure road profile

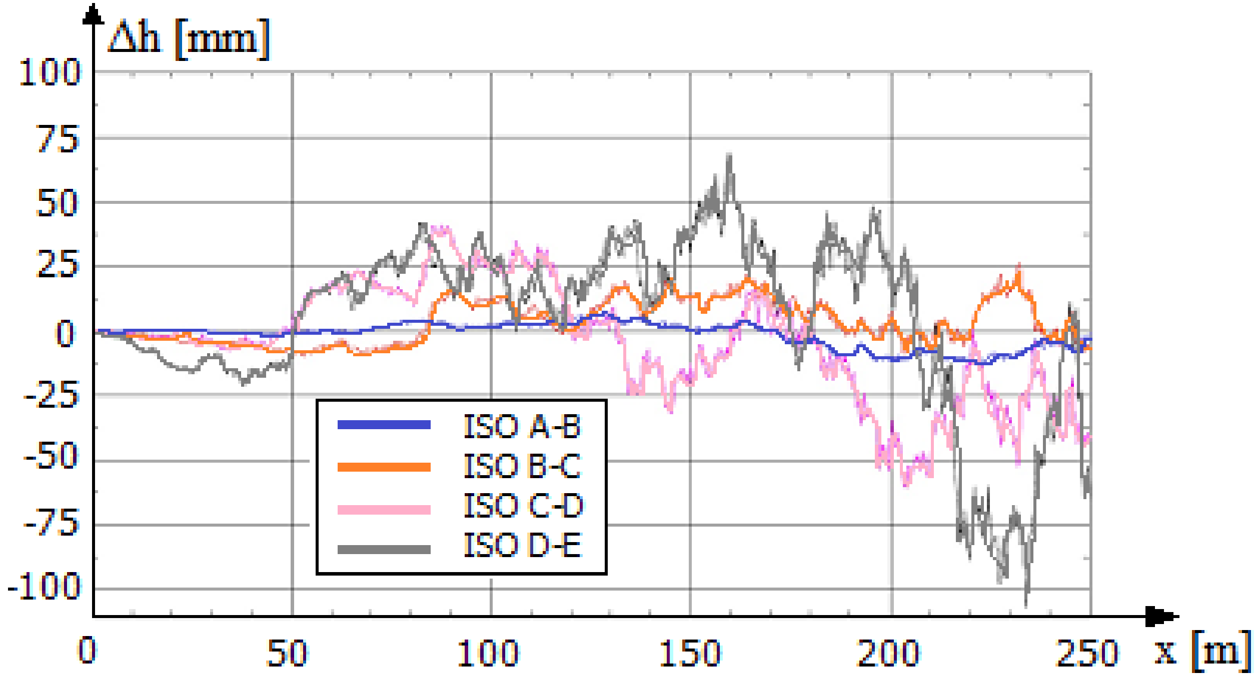




Road profile speed [Km/h]	α [°]	Rconvex [m]	Rconcav [m]
25	8	500	300
30	7,5	800	500
40	7	1000	1000
50	7	1300	1000
60	6,5	1600	1500
80	6	4500	2200
100	5	10000	3000
120	5	18000	6500

Road profile speed [Km/h]	H [m]	h [m]	D [m]	d [m]
25	1.6	0.9	80	48
30	2.2	1.4	120	75
40	2.4	2.4	140	140
50	3.1	2.4	181	140
60	3.3	3.2	207	196
80	8.1	3.9	538	224
100	7.1	2.1	748	263
120	12.2	4.5	1330	480

Annex 2 : Microstructure road profile



Annex 3 : the car parameters

- Unsprung mass, corresponding to the front axle, $m_{S1} = 46$ kg
- Unsprung mass, corresponding to the rear axle, $m_{S2} = 46$ kg
- Sprung mass, corresponding to the front axle (for unladed car weight), $m_1 = 605$ kg;
- Sprung mass, corresponding to the rear axle (for unladed car weight), $m_2 = 495$ kg;
- Sprung mass, corresponding to the front axle (for total car mass), $m_{a1} = 720$ kg;
- Sprung mass, corresponding to the rear axle (for total car mass), $m_{a2} = 880$ kg;
- Front suspension spring rate (for one spring): $k_{S1} = 23\,929$ N/m
- Rear suspension spring rate (for one spring): $k_{S2} = 28500$ N/m
- Front suspension damping (for one damper) $c_{S1} = 1712$ N·s/m
- Rear suspension damping (for one damper): $c_{S2} = 1725$ N·s/m
- Tire stiffness front axle (for one tire): $k_{t1} = 165000$ N/m
- Tire stiffness rear axle (for one tire): $k_{t2} = 165000$ N/m
- Tire damping front axle (for one tire): $c_{t1} = 3430$ N·s/m
- Tire damping rear axle (for one tire): $c_{t2} = 3430$ N·s/m
- Front suspension excitation: X_{r1} – depending on road profile;
- Rear suspension excitation: X_{r2} – depending on road profile.

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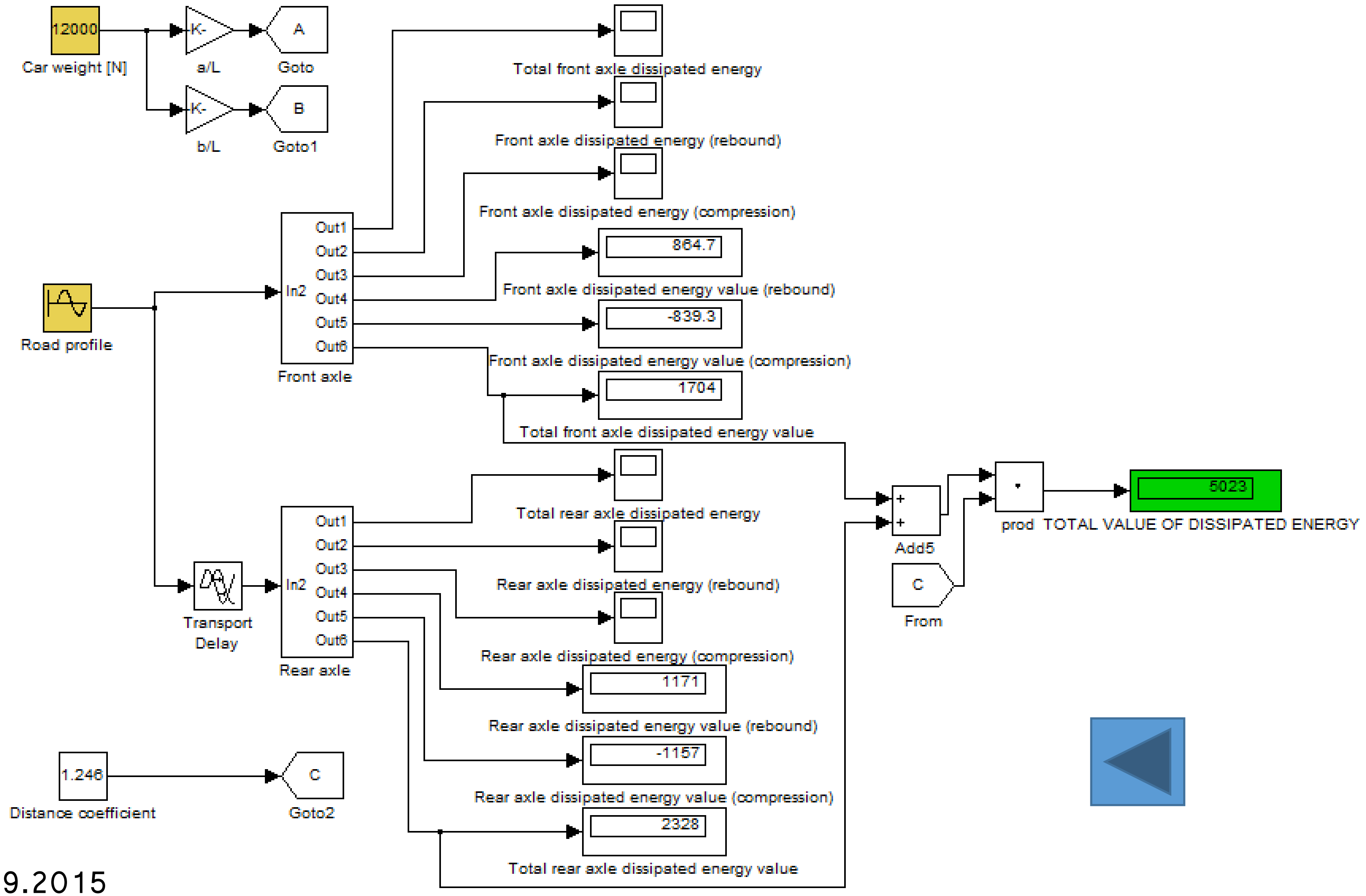
Annex 4 :
Simulink model



Annex 5 : the dissipated energy value [J]

	ISO A-B	ISO B-C	ISO C-D	ISO D-E
25 Km/h	8877	8011	8444	8852
30 Km/h	8610	8491	9920	9905
40 Km/h	6567	6151	8198	8519
50 Km/h	6525	6322	7956	7905
60 Km/h	5914	5954	6755	8125
80 Km/h	5351	5341	6290	6771
100 Km/h	4222	3792	-	-
120 Km/h	3062	-	-	-

The dampers dissipated energy, corresponding to unladed car weight

	ISO A-B	ISO B-C	ISO C-D	ISO D-E
25 Km/h	13930	12380	14760	13650
30 Km/h	13000	12730	15000	15490
40 Km/h	9328	9577	12240	12880
50 Km/h	9363	9482	11960	11670
60 Km/h	8502	8339	9830	11300
80 Km/h	7592	7323	8855	9553
100 Km/h	5735	5449	-	-
120 Km/h	4297	-	-	-

The dampers dissipated energy, corresponding to total car weight