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DYNAMICAL BEHAVIOUR OF A POWERTRAIN

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ABSTRACT: *The paper presents the results of the modeling process of a motor vehicle in order to obtain appropriate parameters for controlling the propulsion system. Are used advanced models of the powertrain and specialized softwares for verifying the theory and equations of the models of the similar models and performance's values for a tested car. The models analyze the whole behavior of the vehicle in different rolling conditions and the results offer exploitation parameters and optimization values for obtaining lower fuel's consumption and lower emissions on different surfaces and roads.*

KEYWORDS: *motor vehicle, powertrain, vehicle dynamics, modeling*

INTRODUCTION

The dynamics of a motor vehicle studies the movement of the motor vehicle and the interaction between the rolling system and the road, taking in consideration all the resistances and influence items that exists and act at an certain moment during the motor vehicle's exploitation.

In order to establish the behavior of a specific motor vehicle response, with the purpose to improve the stability and maneuverability of the vehicle, reducing fuel consumption and noxes and increase the safety and passengers protection during road accidents we need a giant number of research hours, specialized equipments and high quality staff.

In this paper we present the results of modeling and simulation of a motor vehicle using dedicated softwares, starting from the engine and transmission of the car, made with AVL Cruise® and „tested" on a road designed with IPG CarMaker®.

The AVL Cruise consists as an excellent interface and assembling of subassembly models of a motor vehicle's (engines, clutches, gear boxes, transmissions etc.) with the possibility of choosing/modifying values of characteristics or even import them from own data bases. On the other hand, even if in some parts the AVL Cruise and IPG CarMaker overflow, the possibility to „virtually" test a motor vehicle on a specified road/surface is easier on the second software. That's why the two companies decided to a strong collaboration in this field and in offering a complete solution for these purposes.

BUILDING A MODEL

Both software's interfaces are very friendly and help the user to select data for the model from several menus, grouped on specific items. Thus, if we take in consideration the interface from the AVL Cruise, Figure 1, the operation with this software is similar with the Matlab interface, and the modules and associated values of the variables and parameters could be picked from data bases or directly introduced from the keyboard.

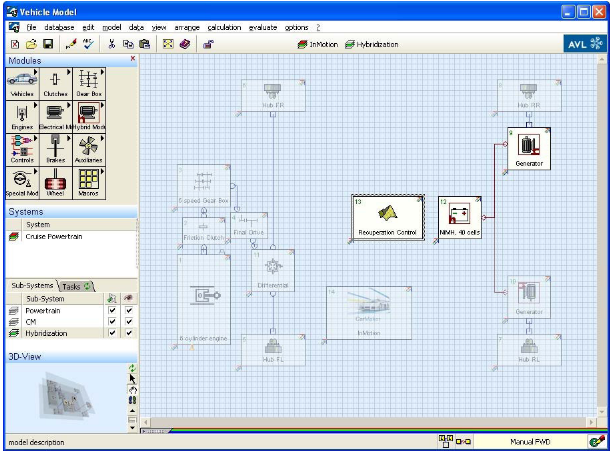
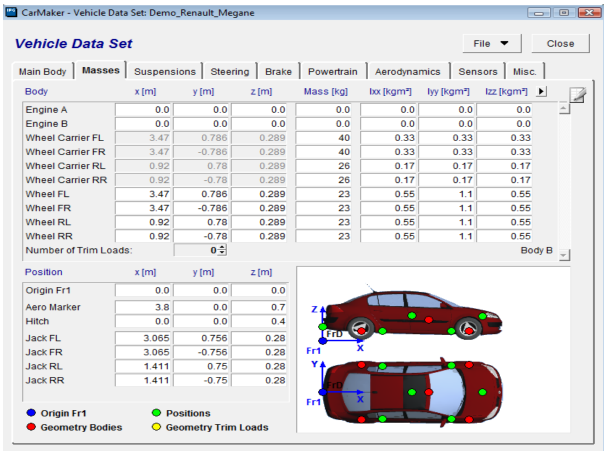


Figure 1. AVL Cruise interface



Body	x [m]	y [m]	z [m]	Mass [kg]	Ixx [kgm²]	Iyy [kgm²]	Izz [kgm²]
Engine A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Engine B	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wheel Carrier FL	3.47	0.786	0.289	40	0.33	0.33	0.33
Wheel Carrier FR	3.47	-0.786	0.289	40	0.33	0.33	0.33
Wheel Carrier RL	0.92	0.78	0.289	26	0.17	0.17	0.17
Wheel Carrier RR	0.92	-0.78	0.289	26	0.17	0.17	0.17
Wheel FL	3.47	0.786	0.289	23	0.55	1.1	0.55
Wheel FR	3.47	-0.786	0.289	23	0.55	1.1	0.55
Wheel RL	0.92	0.78	0.289	23	0.55	1.1	0.55
Wheel RR	0.92	-0.78	0.289	23	0.55	1.1	0.55

Number of Trim Loads: 0

Position	x [m]	y [m]	z [m]
Origin Fr1	0.0	0.0	0.0
Aero Marker	3.8	0.0	0.7
Hitch	0.0	0.0	0.4
Jack FL	3.065	0.756	0.28
Jack FR	3.065	-0.756	0.28
Jack RL	1.411	0.75	0.28
Jack RR	1.411	-0.75	0.28

Figure 2. CarMaker interface

The connections between the modules are conventionally made through wires. Each module could be more or less complex, depending on the „reality” of the car's model, or could exists or not in a specific configuration. The same problem is discussed if the motor vehicle has or not special controls or even hybrid solution.

As we can observe in Figure 2, the CarMaker interface consists also in a multifolders menu, with the possibility of choosing values or inserts them for calculus.

For a complete and extended analysis of the motor vehicle, the AVL Cruise software has direct interfaces with other programs such are AVL BOOST®, FLOWMASTER®, KULI® and of course IPG CarMaker®.

MODEL ANALYSIS

For the simulation and „testing” of the motor vehicle on different road surfaces and configurations and taking in consideration also the driving conditions, we choose the Renault Megane Sedan, with a 1.5 dCI engine, delivering 59 kW power at 3750 rpm and 185 Nm torque at 1900 rpm. The main transmission and the gear box have the following ratio values: i_1= 3.263, i_2= 2.0, i_3= 1,348, i_4= 1.0, i_5= 0.816 and respectively i_0 = 2.829. The vehicle is equipped with standard 195/65/R15 tires. As a design solution the car is „all” in front and the suspension is a conventional one.

The complete analysis consists in evaluating and obtaining direct results of the accelerations, forces, braking moments, gear shifting, slip and stability and fuel consumption of the motor vehicle which follows an imposed road. In Figure 3 is presented the physical model of a vehicle related to a coordinate's reference origin O_o and in Figure 4 the path's configuration of the road which, in our case, consists of 10 segments with a total of 1865 m and with 4 curves, with different slopes and declivity for a sinus steering control.

The tests that we modeled were made for the vehicle with no (zero kg) load and with 300 kg supplementary load. Also the lateral wind has a maximum speed of 80 km/h. The maximum speed that we reach with the vehicle without load was 154 km/h, with 7 km/h above the same considered speed for the 300 kg load.

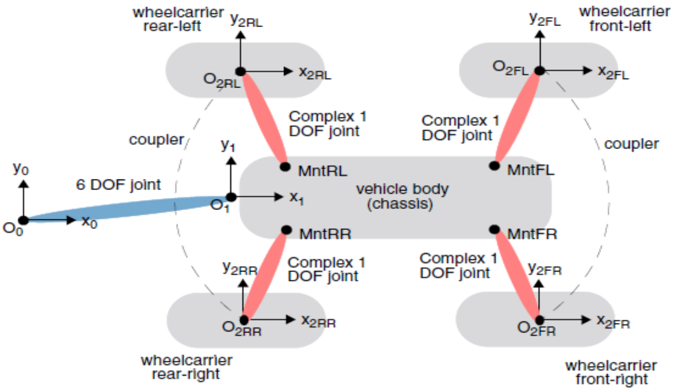


Figure 3. Physical model of the motor vehicle

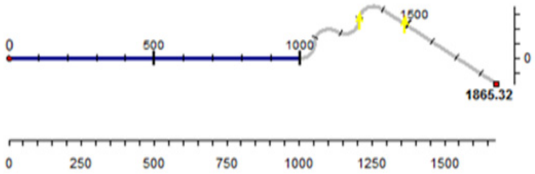


Figure 4. The tested road

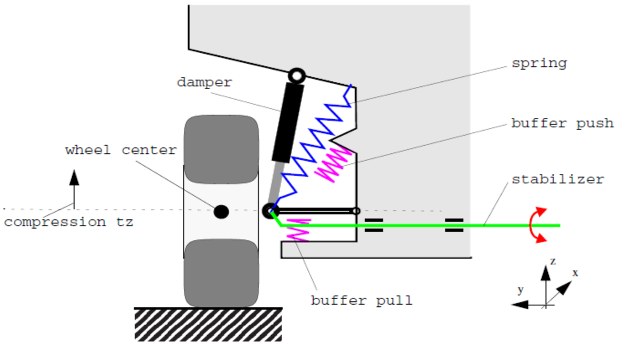


Figure 5. Front-left wheel and suspension

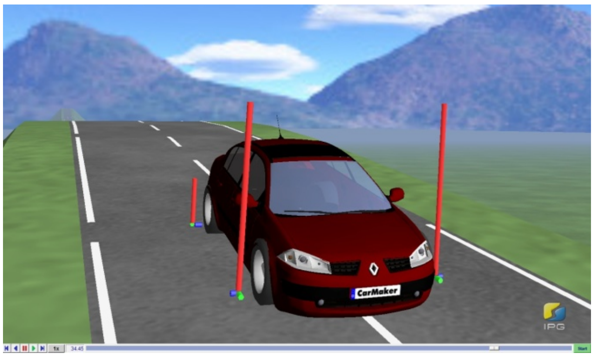
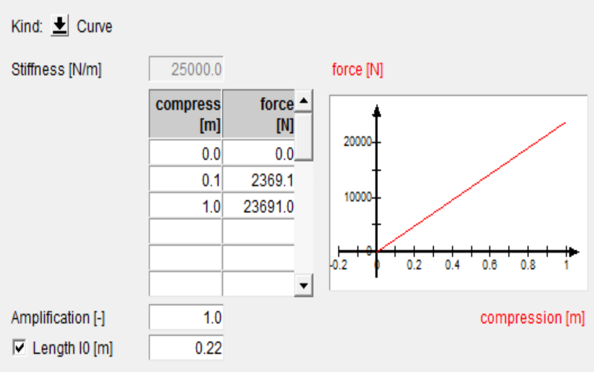


Figure 6. The loads of the car during jumps



Kind: Curve

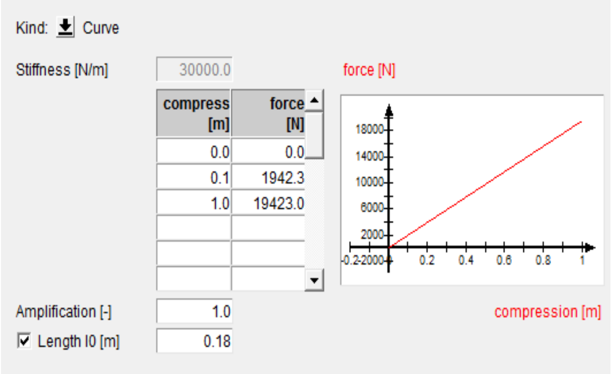
Stiffness [N/m] 25000.0

compress [m]	force [N]
0.0	0.0
0.1	2369.1
1.0	23691.0

Amplification [-] 1.0

☑ Length l0 [m] 0.22

Figure 7. Spring's model of the front axle



Kind: Curve

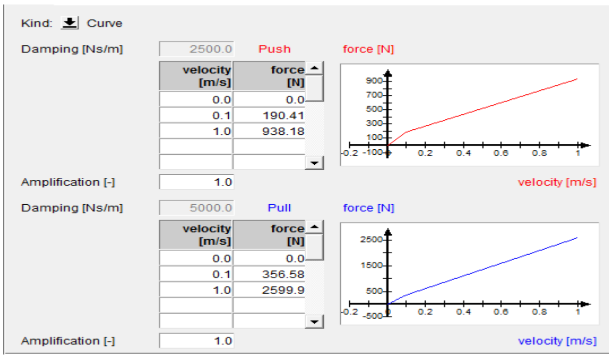
Stiffness [N/m] 30000.0

compress [m]	force [N]
0.0	0.0
0.1	1942.3
1.0	19423.0

Amplification [-] 1.0

☑ Length l0 [m] 0.18

Figure 8. Spring's model of the rear axle



Damping [Ns/m] 2500.0 Push

velocity [m/s]	force [N]
0.0	0.0
0.1	190.41
1.0	938.18

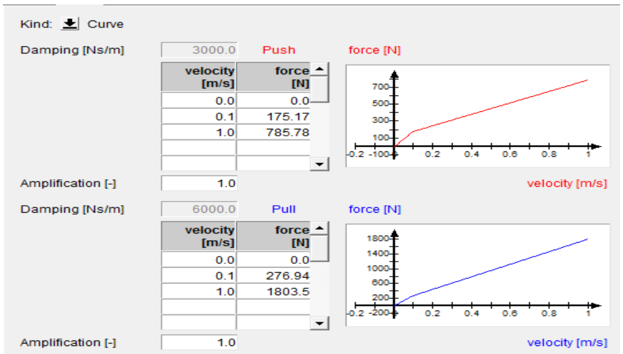
Amplification [-] 1.0

Damping [Ns/m] 5000.0 Pull

velocity [m/s]	force [N]
0.0	0.0
0.1	356.58
1.0	2599.9

Amplification [-] 1.0

Figure 9. Damper's model of the front axle



Damping [Ns/m] 3000.0 Push

velocity [m/s]	force [N]
0.0	0.0
0.1	175.17
1.0	785.78

Amplification [-] 1.0

Damping [Ns/m] 6000.0 Pull

velocity [m/s]	force [N]
0.0	0.0
0.1	276.94
1.0	1803.5

Amplification [-] 1.0

Figure 10. Dampers's model of the rear axle

Figure 5 presents the wheel and suspension configuration of the vehicle for obtaining the loads and reactions. Figure 6 presents the vehicle, rolling on the road surface, with forces/loads on the wheel, accordingly with the "model" and taking in consideration the suspension system (springs and dumpers) and the behavior of this system after jumping the hill.

Figures 7 and 8 presents the modeling of the front an rear axles of the car during the rolling on the surface and Figure 9 and 10 presents the modeling of the suspension system (actually the dumpers) of the front and rear axels.

RESULTS OF THE MODELLING

The results obtained in this analysis, that means the force in the spring, the reaction in the damper and limit and the speed, presented in Figure 11, allows us to try some other possible scenarios and thus in Figures 8 and 9 we present the results obtained for the same vehicle in the following conditions: we keept the 195/65/R15 tires and we change the configuration of the road and of the speed of the car in order to obtain a „fly" of the car. It could be observed the changing in load's aspects and damping during the „landing" of the car and the oscillation of the car during this period.

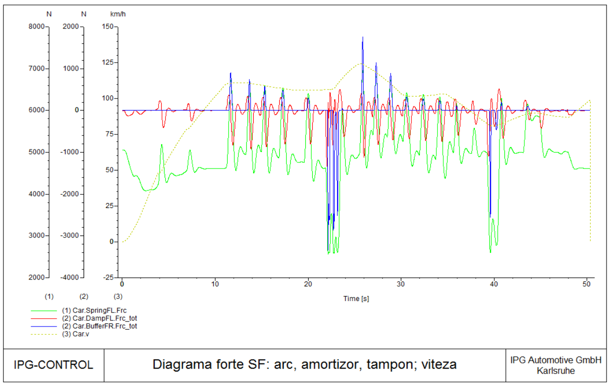


Figure 11. Normal testing conditions

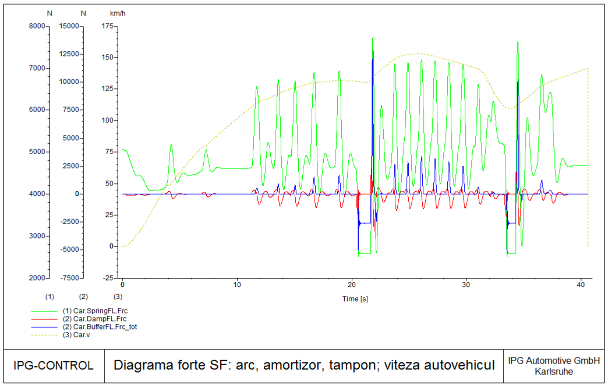


Figure 12. Jumping testing conditions

The diagrams in Figure 11 are obtained for a maximum speed of the vehicle, imposed by the "Speed Control" module, of 110 km/h, thus avoiding the gap between the wheels and road surface. For this situation, before the first downhill of the modelled road, the speed of the vehicle must not exceed 117 km/h. Before the second downhill, in order to keep the contact/adherence between tires and road surface the maximum speed must not exceed 81 km/h.

The diagrams in Figure 12 are obtained for a maximum speed of the vehicle, imposed by the "Speed Control" module, of 150km/h, with detachment of the tires from the road surface. The detachment of the tires from the road surface could be observe on the diagram through the return of the dumper in neutral position. Once the speed up 110 km/h to 150 km/h, we can notice also a significant increase of the spring's, dumper's and limit's forces.

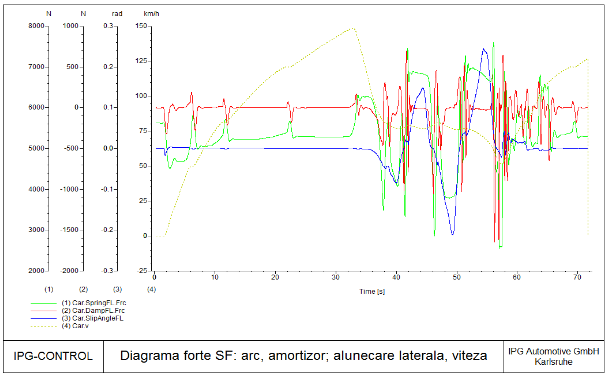


Figure 13. Normal testing conditions

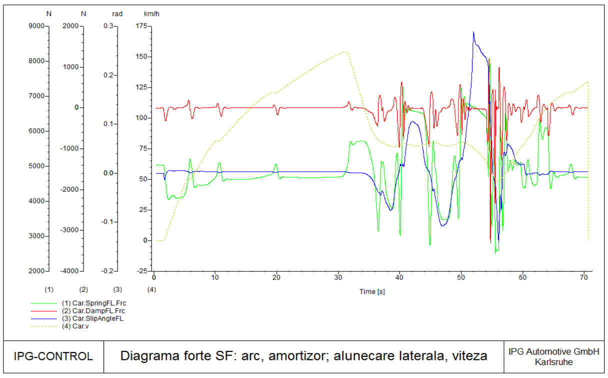


Figure 14. Jumping testing conditions

The diagrams in Figure 13 are obtained for a 300 kg supplementary load of the vehicle. In comparision, the diagrams in Figure 14 are obtained for a zero load, thus the maximum speed increase up to 154 km/h, with 7 km/h more than in the loaded vehicle modelling.

It could be observed the load of the dumper and of the spring of the front left wheel during the braking process, before the first left curve and abruptly unload of the wheel during the left cornering, with the repositioning of the center of gravity of the car's body. When cornering to the right it could be observed almost the same values, but in opposite direction. A lightly slip conditions appears in this situation too.

In the first right curve, the lateral slip angle, belonging the front left tire of the vehicle, results to be 0.15 rad (8.59°) for the loaded vehicle and 0.11 rad (6.3°) for the unloaded one. Thus, the load of the vehicle lead to increasing of the centrifugal force in cornering conditions.

In the second curve (also to the right), with the same bias as the first one, for the unload vehicle the lateral slip angle is 0.28 rad (16.32°) and 0.24 rad (13.86°) for the loaded one.

The possibilities of the analysis are considerable large and we presented only some of the results. The vehicle's characteristics could be modified in AVL Cruise or IPG CarMaker and the road specification and geometry could be easily modified as appropriate.

CONCLUSIONS

The modeling softwares facilitates obtaining experimental results due to the simulations and different models appropriate for different types of cars and on data bases that it have. The results are in matrix shapes, easily to import in spreadsheet, or in graphics shapes. The modeling make possible the reproduction of real scenarios through some conditions (lateral and longitudinal accelerations, different types of tires, suspension elements, steering etc.) that lead to performances of the vehicle and even fuel consumption simulation. Because of the possibility to „push" the testing limits to maximum there are enough safety to preserve the driver health and testing materials.

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