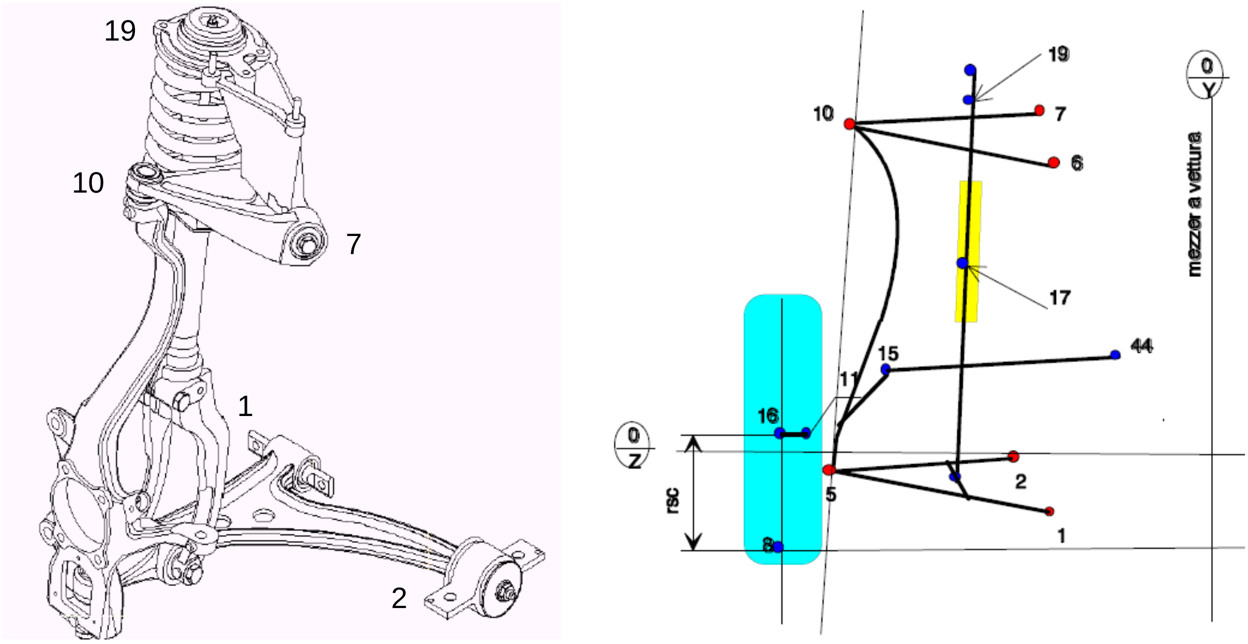
PROJECT 3

Kinematic behavior of a vehicle front suspension

INDEX

EVALUATION OF KINEMATIC BEHAVIOR OF A VEHICLE FRONT SUSPENSION

The aim of this project is to study the kinematic and the static behavior of a high double wishbone front suspension of a front-drive car. As reference model, we use the Alfa Romeo 156 front suspension. Figure 1a sketches the suspension assembly, while Figure 1b shows some characteristic hard-points on the suspension layout. Figure 2 illustrates the front and the lateral views of the same scheme. Tables in file **HardPoints.pdf** collects the hard-points coordinates in the vehicle reference system shown in Figure 3.



a b

Figure 1 3D view of Alfa Romeo 156 high wishbone front suspension, a). Some characteristic points are identified with reference to scheme shown in b).

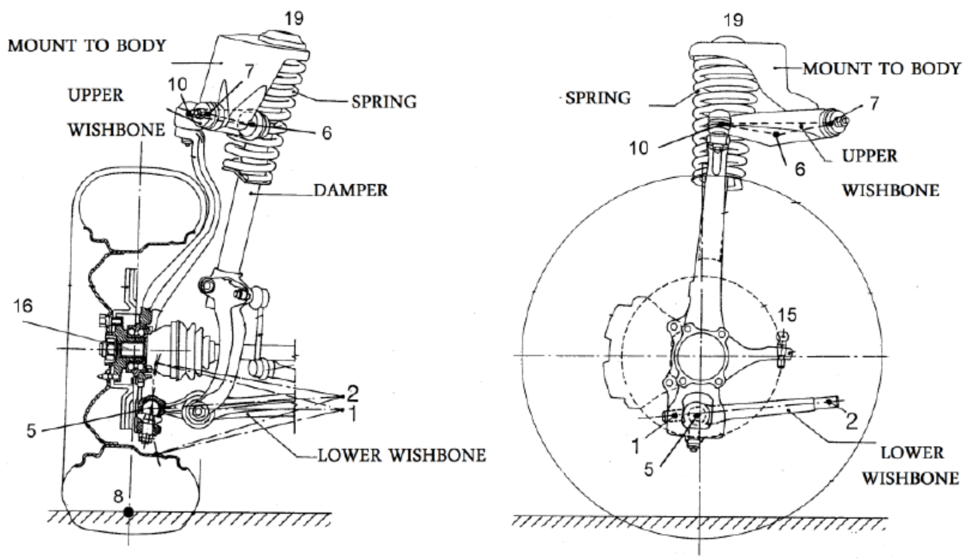


Figure 2 Front and lateral views of Alfa Romeo 156 front suspension. Characteristic hardpoints are enumerated as in the scheme in Figure 1b

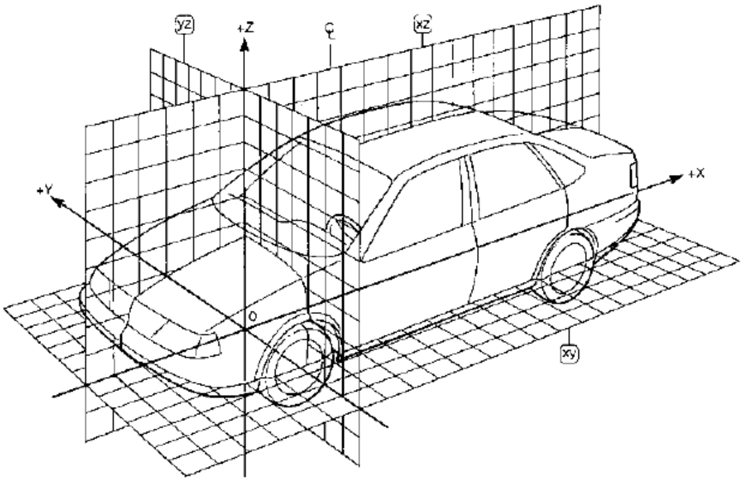
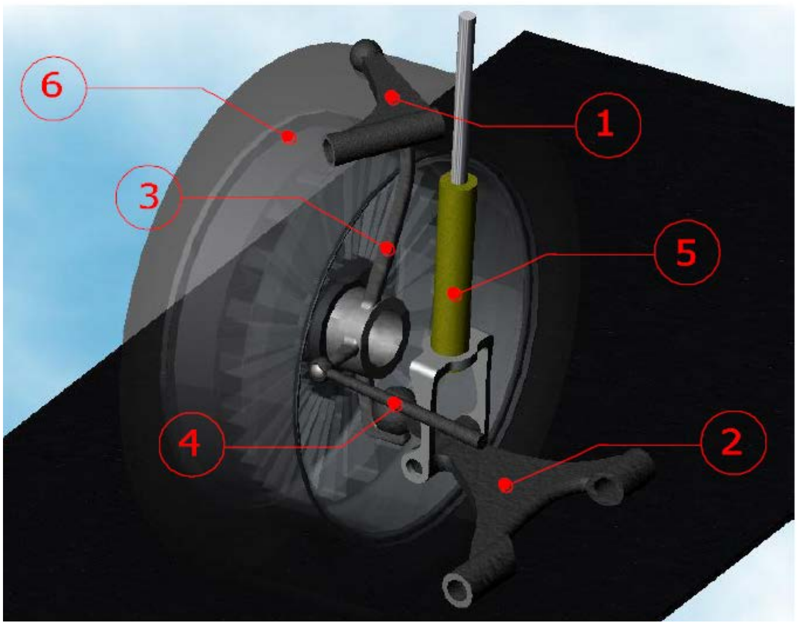


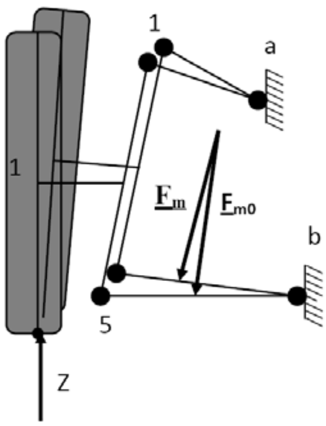
Figure 3 Vehicle reference system adopted. For European car-makers the origin O is at intersection of mid-plane xz with front wheels axes.

a. Model building

It is requested to develop a 3D model of the suspension. It can be developed with many tools (Solid Works, Adams Car using the suspension module or with a in-house model). In detail, it is requested

- to develop the 3 D model of the suspension using the Hard points supplied in appendix,
- to check the correct suspension kinematics. Figure 4 shows a SolidWorks 3D model.
- To plot front, top and side views of the suspension in normal (no bump) condition. Figure 6 shows the front view and the side one.





a b

Figure 4 3D SLDWKS suspension model a) (1-Upper Wishbone, 2-LowerWishbone, 3-Link between hub and upper control arm, 4-Tie-rod, 5-Damper, 6-Wheel) and b) simplified model.

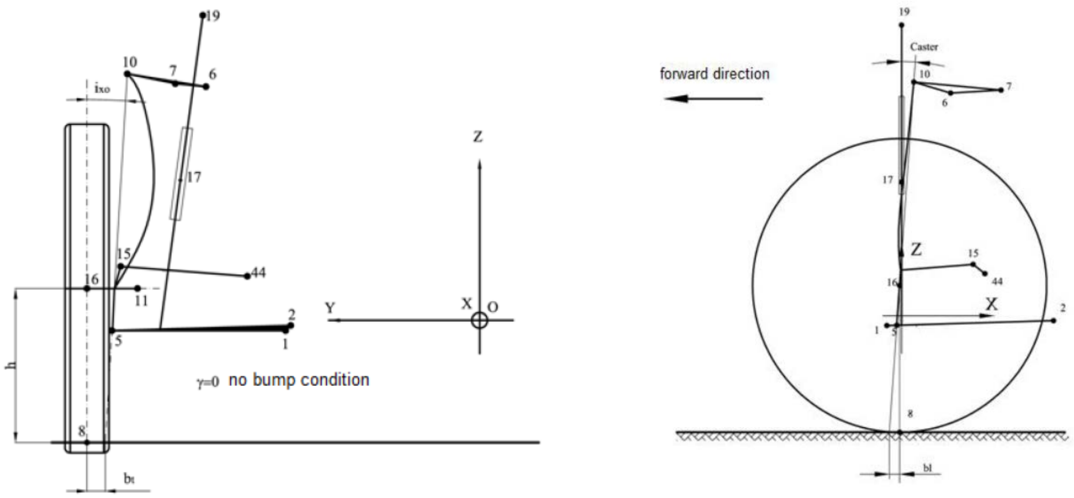


Figure 5 Front and side view in normal (no-bump) condition.

b. Evaluation of kinematic behavior

This section is devoted to evaluating the suspension kinematics.

- Evaluate the suspension kinematic characteristic in normal (no bump) condition,

1) the toe angle (α_0), 2) the camber angle (Υ_0) and 3) the semi-track ($t_0/2$).

Travel	Toe	Camber	Semi-Track
Δz = 0, mm	α_0	Υ_0	$t_0/2$
0.00	-	-	-

- Eevaluate the behavior of previous kinematic characteristic as function of suspension travel. Perform the simulations with a maximum bump-travel as equal to 60 mm and a maximum rebound-travel as equal to 90 mm. Tabulate and plot these kinematic characteristics.

Table 2 Kinematic behavior as function of travel

Travel	Toe	Camber	Semi-Track
Δz = 0, mm	α_0, deg	Υ_0, deg	$t_0/2$, mm
60			
.			
0			
.			
-90			

c. Evaluation of kinematic behavior changing suspension hard-points

Referring to the model update the upper and lower wishbones frame mounts, in particular increase 5 mm the z position of the lower control arm hardpoints and decrease 5 mm the upper control arm. Evaluate the behavior of kinematic characteristic as function of suspension travel. The maximum bump-travel is 60 mm and the maximum rebound-travel is 90 mm. Tabulate and plot these kinematic characteristics.

EVALUATION OF STATIC FORCES ON SUSPENSION

The aim of this section is to evaluate

- the vertical load F_{G0} on the ground when the preload of the spring equals F_{s0}.
- the vertical load F_G on the ground for different suspension travel positions in bound condition (0÷60 mm) and in rebound condition (0÷-90 mm);
- the wheel/ground stiffness K_G.

Spring preload and stiffness are shown in Table 3. Figure 6 shows the force/displacement relation on the spring.

Table 3 Spring stiffness k and preload F_{s0}

Stiffness k, N/mm	24
Pre-load F_{s0}, N	4195

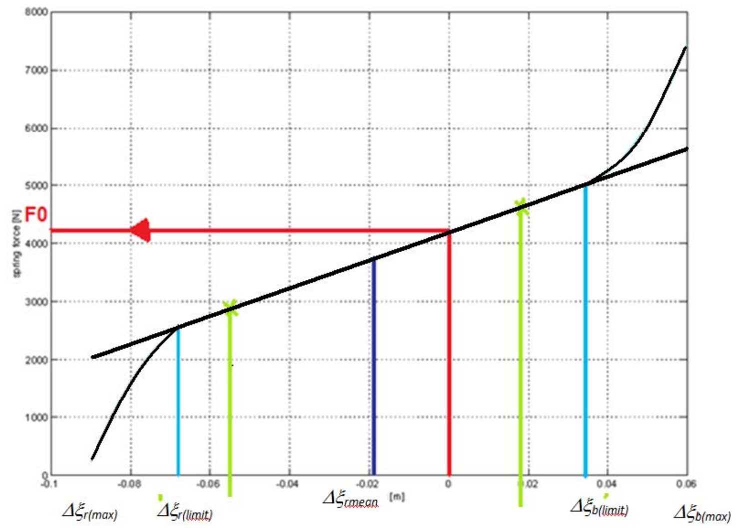


Figure 6 Spring force as function of travel distance

The ground force F_G can be determined from the spring force F_S by applying the virtual work principle,

$$F_G \Delta z = F_S \Delta \xi \ \rightarrow F_S \frac{\Delta \xi}{\Delta z}, \qquad 1$$

where z and ξ are the displacements of the ground contact point and of the spring end respectively. To compute the correct elastic force on the wheel due to the suspension system it is necessary considering that at the suspension end (both in bound and rebound travel) there are bump stops which apply an add-on stiffness. Beforehand estimating the bump-stop intervention point it is necessary to evaluate the spring shortening $\Delta\xi_b$ in bump condition and its lengthening $\Delta\xi_r$ in rebound condition as function of vertical travel z. The mean travel of the spring is

$$\Delta \xi_{mean} = \frac{\Delta \xi_{b(max)} + \Delta \xi_{r(max)}}{2}. \qquad 2$$

This travel can be split into three parts assuming that the bump-stops work only in the last third. These end-stops work only in the range between $\Delta\xi_{b(lim)}$ and $\Delta\xi_{b(max)}$ in bound condition and in the range between $\Delta\xi_{r(lim)}$ and $\Delta\xi_{r(max)}$ in rebound conditions where $\Delta\xi_{b(lim)}$ and $\Delta\xi_{r(lim)}$ are

$$\Delta\xi_{b(lim)} = \Delta\xi_{b(max)} - \frac{\Delta\xi_{b(max)} - \Delta\xi_{mean}}{3} \tag{3}$$

$$\Delta\xi_{r(lim)} = \Delta\xi_{r(max)} - \frac{\Delta\xi_{r(max)} - \Delta\xi_{mean}}{3} \tag{4}$$

respectively. It will be assumed that the bump-stops behave in the same way during bound and rebound conditions and that their force is

$$F_{B(b/r)} = k_B \cdot \left(\Delta\xi_{b/r(max)} - \Delta\xi_{b/r(lim)}\right)^2 \tag{5}$$

where $\Delta\xi_{b/r(lim)} \le \Delta\xi_{b/r} \le \Delta\xi_{b/r(max)}$ and k_B is their stiffness. The stiffness k_B is determined assuming that the bump-stop mean force equals the spring mean force when the spring is at its end-stop,

$$k_S\left(\cdot\, \Delta\xi_{b(max)} - \Delta\xi_{mean}\right) = k_B \cdot \left(\Delta\xi_{b(max)} - \Delta\xi_{b(lim)}\right)^2. \tag{6}$$

Then the vertical force at the ground is F_G is given by Eq. 1

$$F_G = F_{tot}\frac{d\xi}{dz} \tag{7}$$

where F_{tot} is the total static force due to the coil spring and to the bump stop (between $\Delta\xi_{r(lim)}$ and $\Delta\xi_{r(lim)}$ no additional force is given by the bump stops).

According to Table 4, determine and plot

- the vertical force F_G.
- the ground stiffness K_G.

Table 4 elasto-kinematic behavior

z	Δz	ξ	Δξ	F_s	F_B	F_{tot}	F_G	K_G
mm	mm	mm	mm	N	N	N	N	N/mm
60	-	.	-	.	.	.	.	-
.	.	.	.	.	.	.	.	.
0	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
-90	.	.	.	.	.	.	.	.