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How to read a skc file which parameterizes the suspension compliance?

This article is meant as an addition to the article no. 2-002, which describes the content of an skc file with focus on suspension kinematics. Optionally, a compliance characteristic can also be part of a skc file. Learn more in the following about the different compliance models supported by CarMaker!

Compliance of a wheel suspension

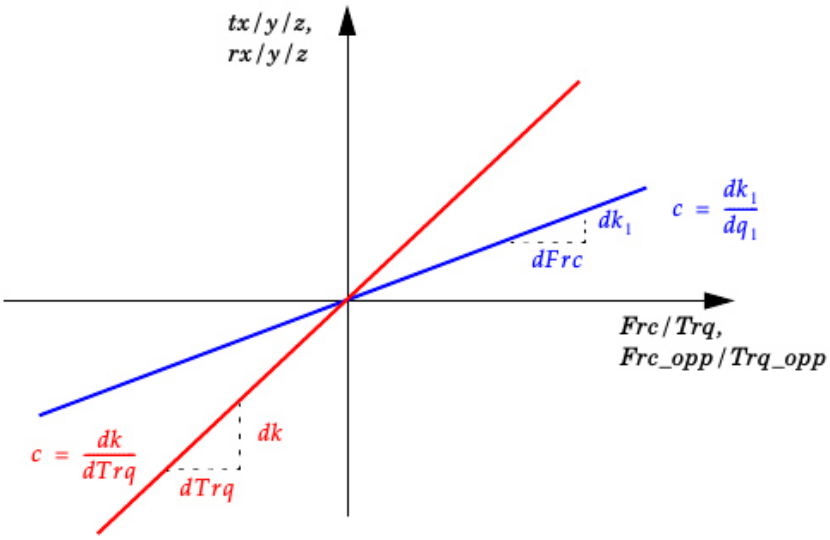
The overall wheel movement is not purely defined by the three degrees of freedom wheel travel, wheel travel opposite wheel and steering rack movement alone. In addition to the forces applied by the suspension force elements like spring, damper, stabilizer and buffer, external forces effect the wheel movement, too. Caused by the elasticity of the suspension elements, an external force or torque applied at the wheel (or opposite wheel) will result in an extra wheel movement. This is what we call *compliance*.

The external inputs are the wheel forces and torques that act on the wheel during a test drive, e.g. during an accelerating/braking maneuver or at corner driving. This results in the following degrees of freedom for the compliance: force x (longitudinal force), force y (lateral force), force z (wheel load, usually not used since it is already considered in the kinematics characteristics for *q0*), torque x, torque y, torque z (self-aligning torque) for both the actual and the opposite wheel.

The bushings and elastically mounted elements such as the chassis subframe have the main influence on the compliance characteristics. Therefore, a vehicle which is not designed for being very comfortable has a neglectable compliance effect. In that case very stiff bushings are used (or no bushings at all), like e.g. in racing cars.

This is the reason why CarMaker offers several compliance models with different levels of detail. It is also possible to deactivate the compliance model completely by using the key *SuspF.Com.N = 0* in the skc file.
If the compliance should be considered, the user can choose between 4 main compliance models, which can be used in the skc file:

- *"Linear Frame Fr1"* and *"Linear Frame Fr2"*:
  These two models are based on a linear relation between external force/torque and wheel movement. As parameter, a single coefficient is used which defines the slope (unit: for tx, ty, tz [m/N] and [1/N]; for rx, ry, rz [rad/N] and [rad/Nm]):



The coefficients can either be defined in the body fixed coordinate system *Fr1* or in the wheel carrier fixed coordinate system *Fr2*. The reference coordinate system is defined by the model kind.

The following example uses *Fr1* as reference coordinate system and defines the compliance at the rear left wheel. It uses linear coefficients to describe the wheel movement in tx, ty, rx, ry, rz under the influence of a longitudinal force (*Frc.x*) and the self-aligning torque (*Trq.z*).

```
SuspR.Com.0.Kind =            CoeffConstFr1
SuspR.Com.0.ValidSide =       left+right
SuspR.Com.0.InputSide =       left
SuspR.Com.0.L.Data.Name =     tx   ty   rx   ry   rz
SuspR.Com.0.L.Frc.Fac2SI =    1.0  1.0  1.0  1.0  1.0
SuspR.Com.0.L.Trq.Fac2SI =    1.0  1.0  1.0  1.0  1.0
SuspR.Com.0.L.Frc.x =  0.170E-07 -0.165E-08-0.501E-08 0.798E-10 -0.146E-07
SuspR.Com.0.L.Trq.z =  0.160E-07 -0.164E-08-0.503E-08 0.796E-10 -0.148E-07
```

- *"Coeff1DFr1"* and *"Coeff1DFr2"*:
  This is again a linear compliance model. However, in this case the coefficients for the linear characteristics depend on the wheel compression. This means, a different characteristic can be defined for different wheel compressions.
  The coefficients can either be defined in the body fixed coordinate system *Fr1* or in the wheel carrier fixed coordinate system *Fr2*. The reference coordinate system is defined by the model kind.
  The following example uses *Fr1* as reference coordinate system and defines the compliance at the rear left wheel. It uses linear coefficients for the wheel movement in *tx, ty, rx, ry, rz* (units: for tx, ty, tz [m/N] and [1/N]; for rx, ry, rz [rad/N] and [rad/Nm])) under the influence of a longitudinal force (*Frc.x*) and the self-aligning torque (*Trq.z*) at three different wheel compressions (-0.01m; 0m; 0.01m).

```
SuspR.Com.0.Kind =            Coeff1DFr1
SuspR.Com.0.ValidSide =       left+right
SuspR.Com.0.InputSide =       left
SuspR.Com.0.L.Arg0 =          -.100E+00 0.000E+00 0.100E+00
SuspR.Com.0.L.Arg0.Fac2SI =   1.0
```

```
SuspR.Com.0.L.Data.Name =     tx   ty   rx   ry   rz
SuspR.Com.0.L.Frc.Fac2SI =    1.0  1.0  1.0  1.0  1.0
SuspR.Com.0.L.Trq.Fac2SI =    1.0  1.0  1.0  1.0  1.0
SuspR.Com.0.L.Frc.x.Data:
       0.170E-07 -0.165E-08-0.501E-08 0.798E-10 -0.146E-07
       0.160E-07 -0.164E-08-0.503E-08 0.796E-10 -0.148E-07
       0.180E-07 -0.166E-08-0.505E-08 0.794E-10 -0.150E-07
SuspR.Com.0.L.Trq.z.Data:
       -0.501E-08 0.790E-07 0.410E-06 -0.130E-14 0.550E-08
       -0.503E-08 0.794E-07 0.411E-06 -0.123E-14 0.558E-08
       -0.505E-08 0.798E-07 0.412E-06 -0.116E-14 0.566E-08
```

- *"Displace1DFr1"* and *"Displace1DFr2"*
  This model is the first of two non-linear compliance models. The wheel displacement is defined by data points instead of coefficients, which depend on the forces and torques of the actual and opposite wheel.
  The wheel displacement can either be defined in the body fixed coordinate system *Fr1* or in the wheel carrier fixed coordinate system *Fr2.* The reference coordinate system is defined by the model kind.
  The example below shows the wheel displacement of the front left wheel in *ty* and *rz* direction (with units: m and rad), measured under the influence of a longitudinal force (*Frc.x*), ranging between 0kN and 4,7kN. *Fr1* is used as reference coordinate system.

```
SuspF.Com.0.Kind =          Displace1DFr1 1
SuspF.Com.0.ValidSide =     left+right
SuspF.Com.0.InputSide =     left
SuspF.Com.0.L.Arg =         Frc.x
SuspF.Com.0.L.Arg0 =        0.0 1.0 2.0 3.0 4.0 4.5 4.6 4.7
SuspF.Com.0.L.Arg0.Fac2SI = 1.0e3
SuspF.Com.0.L.Data.Name =   ty     rz
SuspF.Com.0.L.Data.Fac2SI = 1.0    1.32456
SuspF.Com.0.L.Data:
   0.000      0.000
   0.001      0.006
   0.002      0.011
   0.004      0.015
   0.008      0.018
   0.016      0.020
   0.032      0.021
   0.032      0.021
…
```

- *"Displace2DFr1"* and *"Displace2DFr2"*
  This is the most accurate compliance model, which describes the wheel movement based on both the wheel compression and the forces/torques at the actual or opposite wheel. Optionally, the forces/torques at the actual wheel can be used in combination with the forces/torques of the opposite wheel (since CarMaker 6.0).
  The wheel displacement can either be defined in the body fixed coordinate system *Fr1* or in the wheel carrier fixed coordinate system *Fr2.* The reference coordinate system is defined by the model kind.
  The example below shows a compliance definition of the rear left wheel, in which the wheel displacements in *tx, ty, tz, rx, ry, rz* (units: m and rad) depend on both the wheel compression (*comp, Arg0*) and the wheel force (*Frc.x/Frc.y, Arg1*). The wheel compression ranges between +/-0.01m with a step size of 0.05m, and the forces range between +/-850N. For each combination of compression and force, the wheel displacement is measured. The file syntax is

similar to the kinematics part of the skc-file: The first column of the data table refers to the elements of Arg0 (wheel compression), the second column links with the vector Arg1 (Frc.x). The first block uses a constant wheel compression of -0.01m with a varying longitudinal force. For each combination, the wheel displacement is defined.
In the second block, the wheel compression uses the last value of vector Arg0 (0.01m) and combines it again with all values for the longitudinal force. The second table does the same for a lateral force as input.

```
SuspR.Com.N =                 2
SuspR.Com.0.Kind =            Displace2DFr1 1
SuspR.Com.0.ValidSide =       left+right
SuspR.Com.0.InputSide =       left
SuspR.Com.0.L.Arg =           comp Frc.x
SuspR.Com.0.L.Arg0 =          -.100E+00 -.050E+00 0.000E+00 0.050E+00 0.100E+00
SuspR.Com.0.L.Arg0.Fac2SI =   1.0
SuspR.Com.0.L.Arg1 =          -.850E+05 -.425E+05 0.000E+00 0.425E+05 0.850E+05
SuspR.Com.0.L.Arg1.Fac2SI =   1.0
SuspR.Com.0.L.Data.Name =       %i0     %i1    tx     ty     tz     rx     ry     rz
SuspR.Com.0.L.Data.Fac2SI =      1       1     1.0    1.0    1.0    1.0    1.0    1.0
SuspR.Com.0.L.Data:
   0  0    -0.155E-02 0.151E-03 0.710E-03 0.430E-03 -0.788E-05 0.146E-02
   0  1    -0.775E-03 0.075E-03 0.355E-03 0.215E-03 -0.003E-03 0.730E-03
   0  2    0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
   0  3    0.780E-03 -0.084E-03 -0.392E-03 -0.233E-03 0.003E-03 -0.730E-03
   0  4    0.156E-02 -0.168E-03 -0.784E-03 -0.467E-03 0.597E-05 -0.146E-02
   ...
   4  0    -0.115E-02 0.111E-03 0.670E-03 0.390E-03 -0.748E-05 0.106E-02
   4  1    -0.575E-03 0.055E-03 0.335E-03 0.195E-03 -0.004E-03 0.530E-03
   4  2    0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
   4  3    0.580E-03 -0.064E-03 -0.372E-03 -0.213E-03 0.003E-03 -0.530E-03
   4  4    0.116E-02 -0.128E-03 -0.744E-03 -0.427E-03 0.557E-05 -0.106E-02
SuspR.Com.1.Kind =            Displace2DFr1 1
SuspR.Com.1.ValidSide =       left+right
SuspR.Com.1.InputSide =       left
SuspR.Com.1.L.Arg =           comp Frc.y
SuspR.Com.1.L.Arg0 =          -.100E+00 -.050E+00 0.000E+00 0.050E+00 0.100E+00
SuspR.Com.1.L.Arg0.Fac2SI =   1.0
SuspR.Com.1.L.Arg1 =          -.850E+05 -.425E+05 0.000E+00 0.425E+05 0.850E+05
SuspR.Com.1.L.Arg1.Fac2SI =   1.0
SuspR.Com.1.L.Data.Name =     %i0     %i1     tx     ty     tz     rx     ry     rz
SuspR.Com.1.L.Data.Fac2SI =   1       1       1.0    1.0    1.0    1.0    1.0    1.0
SuspR.Com.1.L.Data:
   ...
```