Vehicle Dynamics First Assignment 2022/2023

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Assignment description

In this first assignment, the MF96 tyre model coefficients, have been fitted starting from the raw data collected for a set of F-SAE tyre, in particular the tyre chosen to perform the fitting are the Hoosier $6.0/18.0 - 10$ LCO. The raw data have been plotted and divided in sub-tables, necessary to intersect the data and perform the subsequent computations. By taking as input the slip ratio $\kappa[-]$, the slip angle $\alpha[rad]$, the camber angle $\gamma[rad]$ and the load $Fz[N]$, it was possible to compute the parameters of the semi-empirical "Pacejka model" of the longitudinal force Fx, the lateral force Fy, and self-aligning torque Mz. The results are reported below in the following set of tables. The parameters fitted are listed in the same order used during the fitting procedure. At the end of every evaluation the R^2 value has been printed to have an indication of the quality of the results obtained. Moreover, some representative plots were included, in which the measured forces Fx and Fy and the self-aligning torque Mz are shown alongside the estimated forces and torques computed with the fitted model.

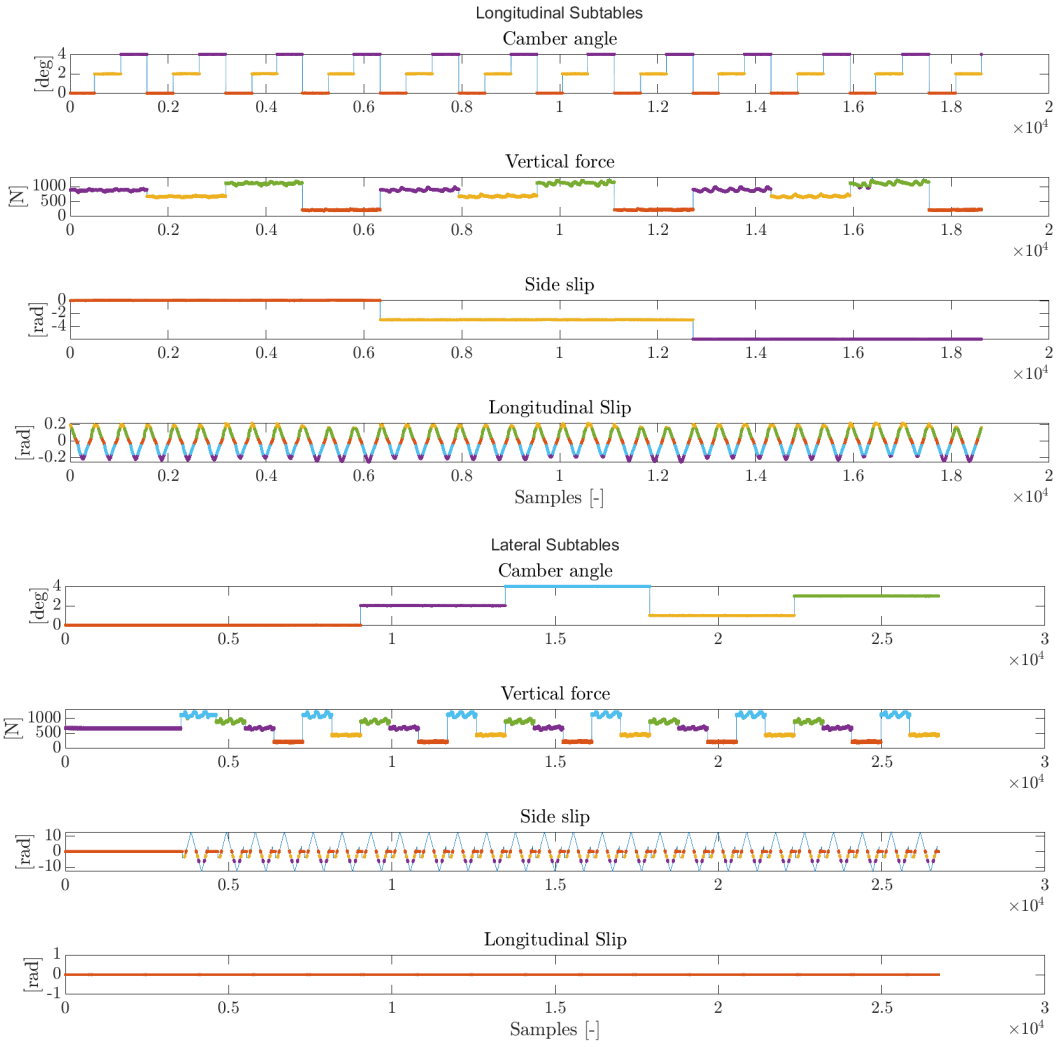
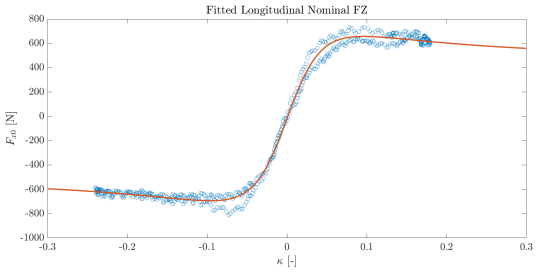


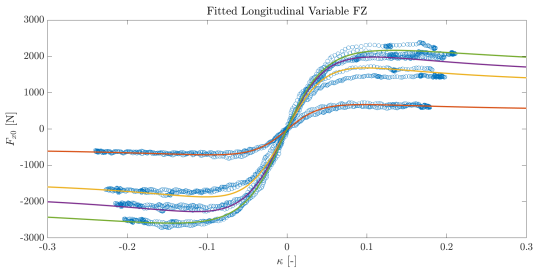
Figure 1: Longitudinal and Lateral Subtables.

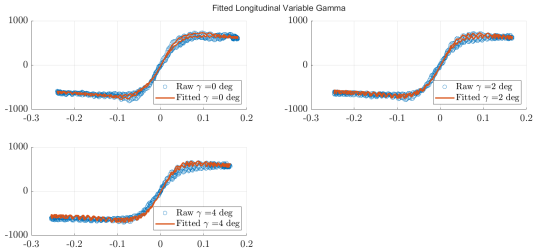
Longitudinal Forces

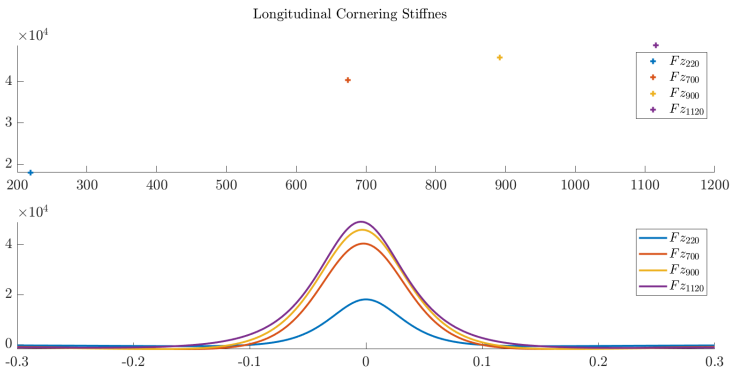
To fit the coefficient related to longitudinal forces the computation has been performed considering, at first, a nominal value for vertical force, then a variable load and finally a variable camber angle. The nominal value for the vertical force has been set equal to $Fz = 220[N]$. An initial guess $P0$, for the value of the parameters that need to be optimised has been set, and, also, some limitation on upper boundaries ub and lower boundaries lb have been introduced before starting the minimization procedure. The Longitudinal cornering stiffness has also been computed. The $P0, lb, ub$ chosen, the fitted coefficients' values and the residuals' ones are listed in the following table.

Dataset Hoosier_B1464run30	
Longitudinal Force with Fz=220N; camber=0; alpha = 0	
P0 = [1, 2, 1, 0, 0, 75, 0]	
Lb = [1, 0.1, 0, 0, -10, 0, -10]	
Ub = [2, 4, 1, 1, 10, 100, 10]	
Parameters Fitted	**Value**
pCx1	*1.539*
pDx1	*3.147*
pEx1	*0.012*
pEx4	*0.078*
pKx1	*82.430*
pHx1	*-2.36e-05*
pVx1	*-0.086*
R^2	*0.995*
Longitudinal Force with variable Fz**;** $\gamma = 0$**;** $\alpha = 0$	
P0 = [-0.1,0,0,0,0,0,0]	
Lb = [-1,-1,-1,-1,-100,-10,-1]	
Ub = [0,1,1,1,100,10,1]	
pDx2	*-0.025*
pEx2	*-0.036*
pEx3	*0.106*
pKx2	*-0.002*
pKx3	*0.015*
pHx2	*0.011*
pVx2	*-0.056*
R^2	*0.997*
Longitudinal Force with variable Fz**; variable** γ**;** $\alpha = 0$	
P0 = [15]	
Lb = [10]	
Ub = [20]	
pDx3	*17.932*
R^2	*0.991*





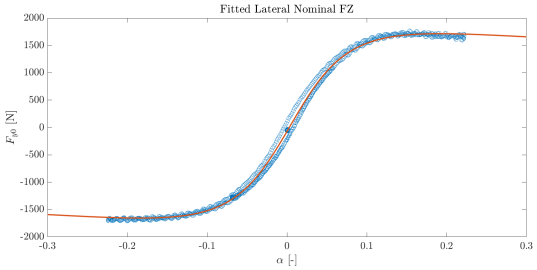


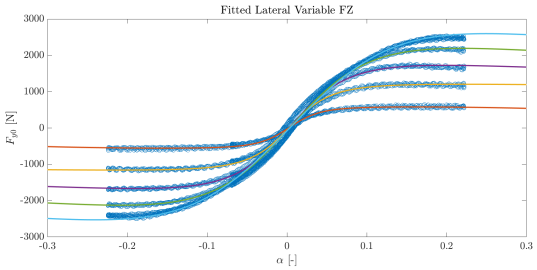


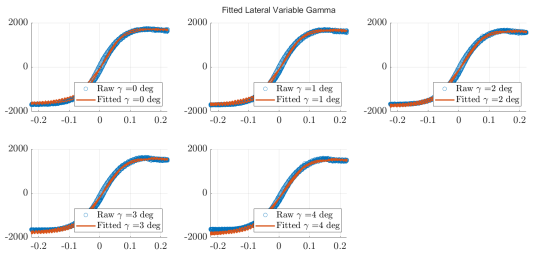
Lateral Forces

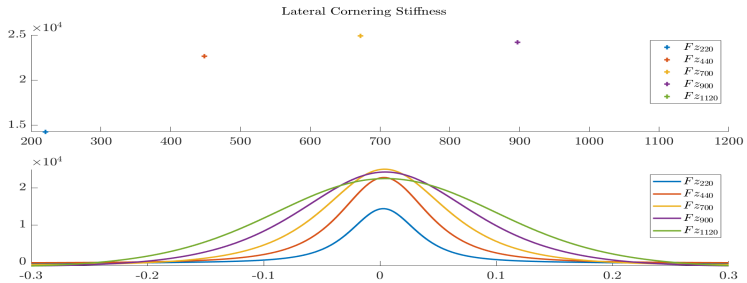
Following a similar procedure, as for the longitudinal force fitting, the lateral forces computation has been performed. The nominal value for the vertical force has been set equal to $Fz = 700[N]$. An initial guess $P0$, for the value of the parameters that need to be optimised has been set, and, also, some limitation on upper boundaries ub and lower boundaries lb have been introduced before starting every minimization procedure. The $P0, lb, ub$ chosen, the fitted coefficients' values and the residuals' values are listed in the following table.

Dataset Hoosier_B1464run23	
Lateral Force with Fz=700N; camber=0; alpha = 0	
P0 = [-2,-2,0,0,35,1,0]	
Lb = [-10,-7,-1,-1,20,0,-1]	
Ub = [0,0,1,1,50,2,1]	
Parameters Fitted	**Value**
pCy1	*-1.593*
pDy1	*-2.505*
pEy1	*0.340*
pHy1	*-0.004*
pKy1	*35.748*
pky2	*0.996*
pVy1	*0.044*
R^2	*0.998*
Lateral Force with variable Fz**;** $\gamma = 0$**;** $\alpha = 0$	
P0 = [1,0,0,1]	
Lb = [-10,-10,-10,-10]	
Ub = [10,10,10,10]	
pDy2	*0.355*
pEy2	*-1.230*
pHy2	*-0.002*
pVy2	*-0.021*
R^2	*0.997*
Lateral Force with variable Fz**; variable** γ**;** $\alpha = 0$	
P0 = [1,1,1,1,0,0,0]	
Lb = [-3,0,-2,0,0,-4,-1]	
Ub = [3,2,2,2,2,1,1]	
pDy3	*2.990*
pEy3	*1.406*
pEy4	*1.988*
pHy3	*6.78e-05*
pKy3	*1.774*
pVy3	*-3.593*
pVy4	*0.056*
R^2	*0.995*









1 Combined case

Using the information derived from both longitudinal and lateral pure slip model the parameters for combined model, have been fitted. To obtain the coefficient the lateral data-set has been used and the Fx and Fy value evaluated. Since only few values of α have been provided, the Lateral force has been plotted as function of the longitudinal slip κ keeping the value of α constant. Then the weighting function Gxa and Gyk as function of the longitudinal and lateral slip have been plotted.

Combined Lateral case with $Fz = Fz_nom$**;** $\gamma = 0$	
P0 = [14,13,-0.49,0.9,0.03,-0.27,3.76,-0.09,28.38]	
Lb = [-5,-5,-5,-5,-5,-5,-5,-5,-5]	
Ub = [20,20,20,20,20,20,20,20,20]	
rBy1	*13.048*
rBy2	*19.989*
rBy3	*-0.054*
pCy1	*1.002*
pHy1	*0.019*
pVy1	*1.044*
rVy4	*7.470*
rVy5	*-0.031*
rVy6	*16.333*
R^2	*1.000*
Combined Longitudinal case with $Fz = Fz_nom$**;** $\gamma = 0$	
P0 = [15,12,1,0]	
Lb = [-20,-20,-20,-20,]	
Ub = [20,20,20,20]	
rBx1	*19.925*
rBx2	*16.723*
rCx1	*1.102*
rHx1	*0.005*
R^2	*0.997*

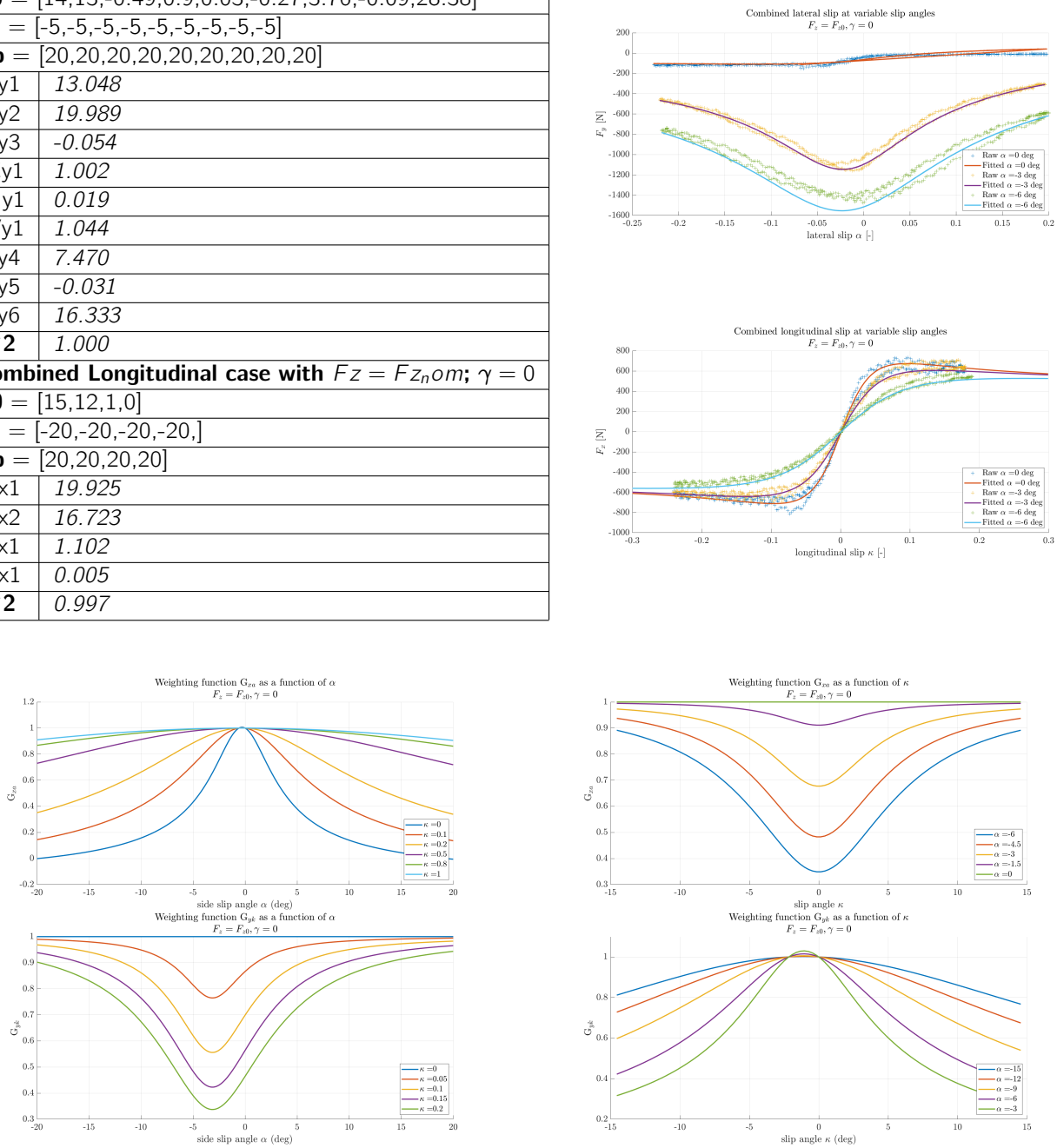


Figure 2: Weighting functions

Aligning Moment

To fit the aligning moment a similar procedure has been followed. Starting from the previously fitted parameters, the values related to the aligning moment have been calculated. The vertical force nominal value has been set at $Fz = 700N$ then the coefficients related to variable load and variable camber have been defined. Since the performed fitting did not lead to acceptable Residuals values, an $LSP - based$ optimizer was implemented to find the best fit for the parameters. Due to high computational costs, though, this solution was not feasible with the available time and resources. In fact, as the number of iteration was not sufficient, the solutions found by the optimizer were of lower quality than the ones found through trial and error.

Dataset Hoosier_B1464run23	
Aligning Moment with Fz=700N; camber=0; alpha = 0	
P0 = [10, 13,1.28,1.28,-0.16,-0.2,-0.032,0,0,0,0.28,-0.005]	
Lb = [7,10,0.5,0.5,-1,-1,-1,-1,-1,-2,-10,-1]	
Ub = [15,16,2,2,0,1,1,1,1,0,3,0]	
Parameters Fitted	**Value**
qBz1	*10.417*
qBz9	*12.995*
qBz10	*1.284*
qCz1	*1.296*
qDz1	*-0.158*
qDz2	*-0.074*
qDz3	*-2.151*
qDz4	*0.339*
qDz6	*-2.93e-04*
qEz1	*-0.020*
qEz4	*1.541*
qHz1	*-0.087*
R^2	*0.931*
Aligning Moment with variable Fz**;** $\gamma = 0$**;** $\alpha = 0$	
P0 = [1.9, 0.2, 0, 0, -0.01]	
Lb = [-5, -5, -1, -1, -1]	
Ub = [5, 5, 1, 1, 1]	
qBz2	*1.635*
qBz3	*-0.133*
qDz7	*0.022*
qEz2	*0.071*
qEz3	*-0.069*
R^2	*0.957*
Aligning Moment with variable Fz**; variable** γ**;** $\alpha = 0$	
P0 = [-1.4, 0.9, -2, -1.8, 1.5, -1, 1, 0.65, 0.07]	
Lb = [-3, 0, -2.5, -2.5, 0, -5, -1, -1, -1]	
Ub = [3, 2, 2, 2, 2, 5, 2, 1, 1]	
qBz4	*-1.298*
qBz5	*0.732*
qDz3	*-2.152*
qDz4	*0.331*
qDz8	*1.490*
qDz9	*-0.959*
qEz5	*1.991*
qHz3	*0.648*
qHz4	*-0.226*
R^2	*0.800*