Sensitivity analysis of tire model micro-coefficients

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1. The overview

Introduction

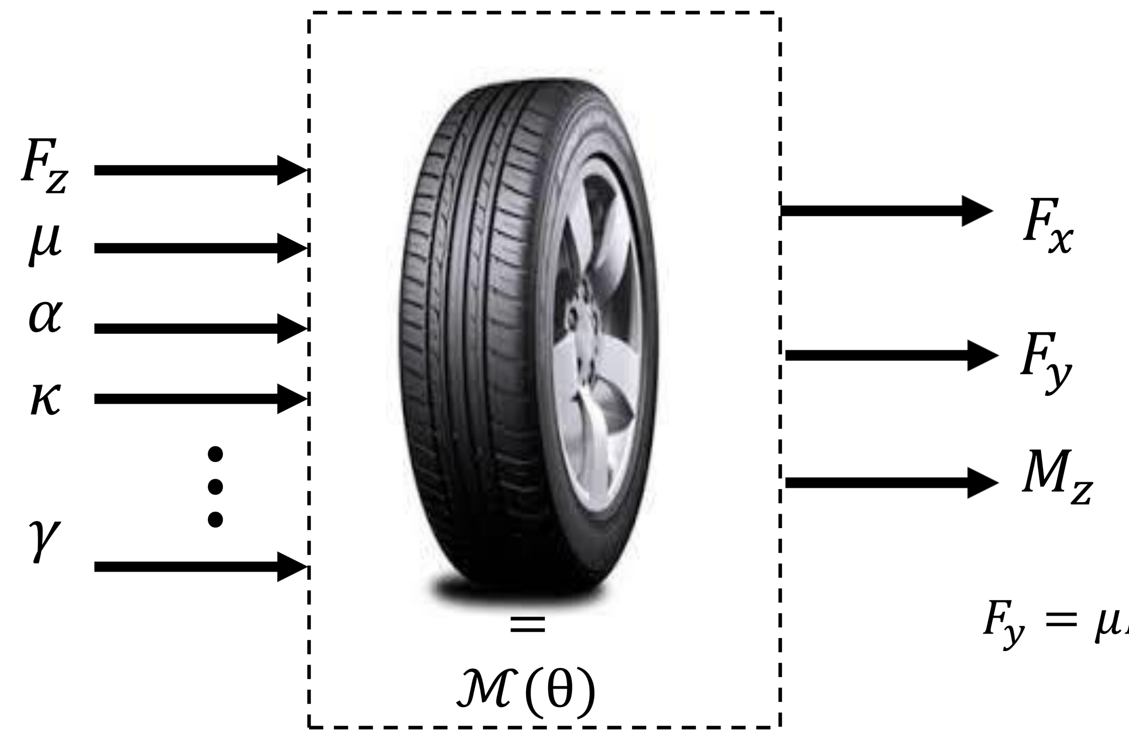
Tires are a vehicle's most important safety features. Indeed, tires are required to produce the forces necessary to control the vehicle. Various models have been proposed to describe the behavior of the tire on the ground. These models depend of numerous parameters which can be distinguished in macro and micro parameters. One semi-empirical model commonly used in vehicle dynamics simulations, was developed by Pacejka [1]. It is widely used to calculate steady-state tire force and moment characteristics. This model depends on various parameters.

In [2], it has been shown that the lateral stiffness K_y and the slip angle are the parameters affecting the lateral force variation. However, the lateral stiffness K_y depends on numerous parameters.

Aim

- To quantify the influence of micro-parameters of Pacejka model on the lateral stiffness K_y and, therefore, on lateral force.

2. Model

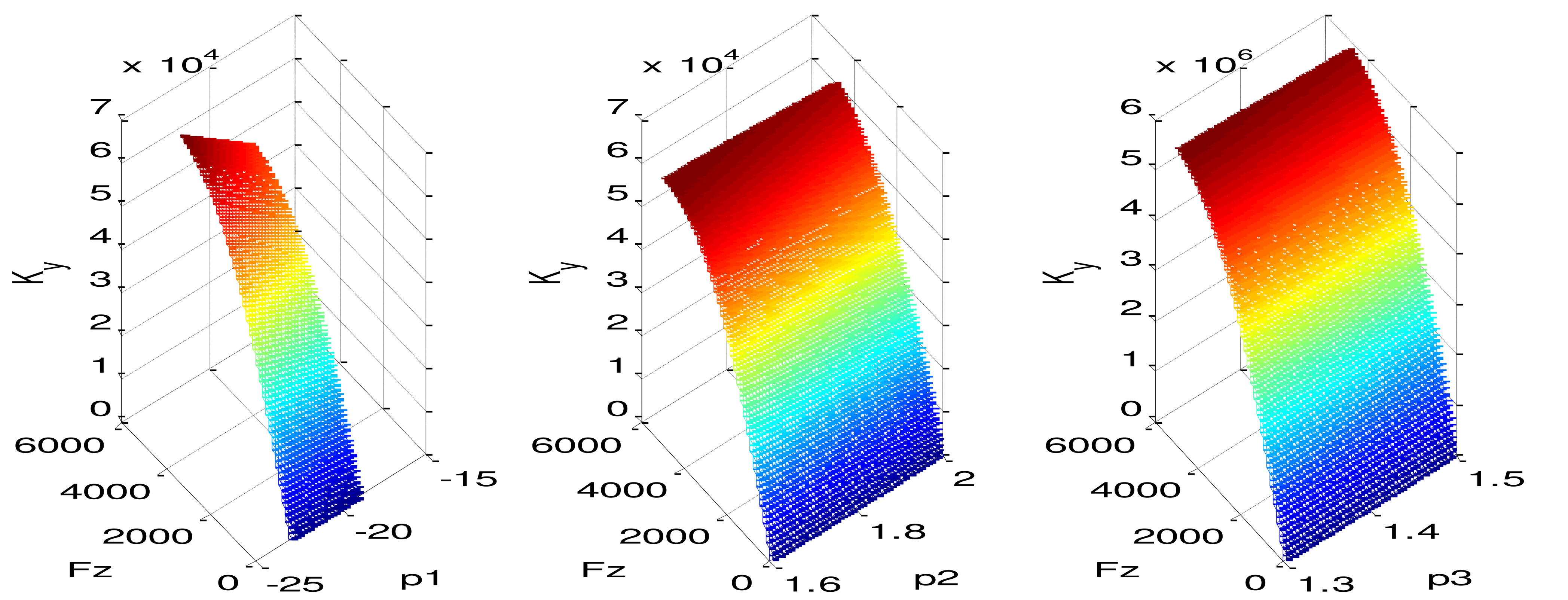


- $[F_z, \mu, \alpha, \kappa, \gamma]$ input variables
- θ micro-coefficients
- $[F_y]$ the pure lateral force considered as the output model and given by:

$$F_y = \mu F_z \sin\left(C \arctan\left(B(\alpha + S_h) - E\left(B(\alpha + S_h) - \arctan\left(B(\alpha + S_h)\right) \right) \right) \right) + S_v$$

The tire lateral stiffness K_y is obtained as a function of the vertical load F_z and the camber angle

$$K_y = p_1 F_z sin\left(2arctan\left(\frac{F_z}{p_2 F_{z_0}} \right) \right) (1 - p_3|\gamma|)$$



Graphical representation of lateral stiffness K_y as a function of vertical load F_z and micro-coefficients p_1, p_2 and p_3

3. Polynomial chaos

- The micro-coefficients are assumed to be independent. The output can be approximated by a sum of polynomial chaos as follows [3]:

$$y \approx \sum_{j=0}^{M} c_j \psi_j (u_1, \cdots, u_n)$$

- The first order sensitivity index is computed from polynomial chaos coefficient s and given as:

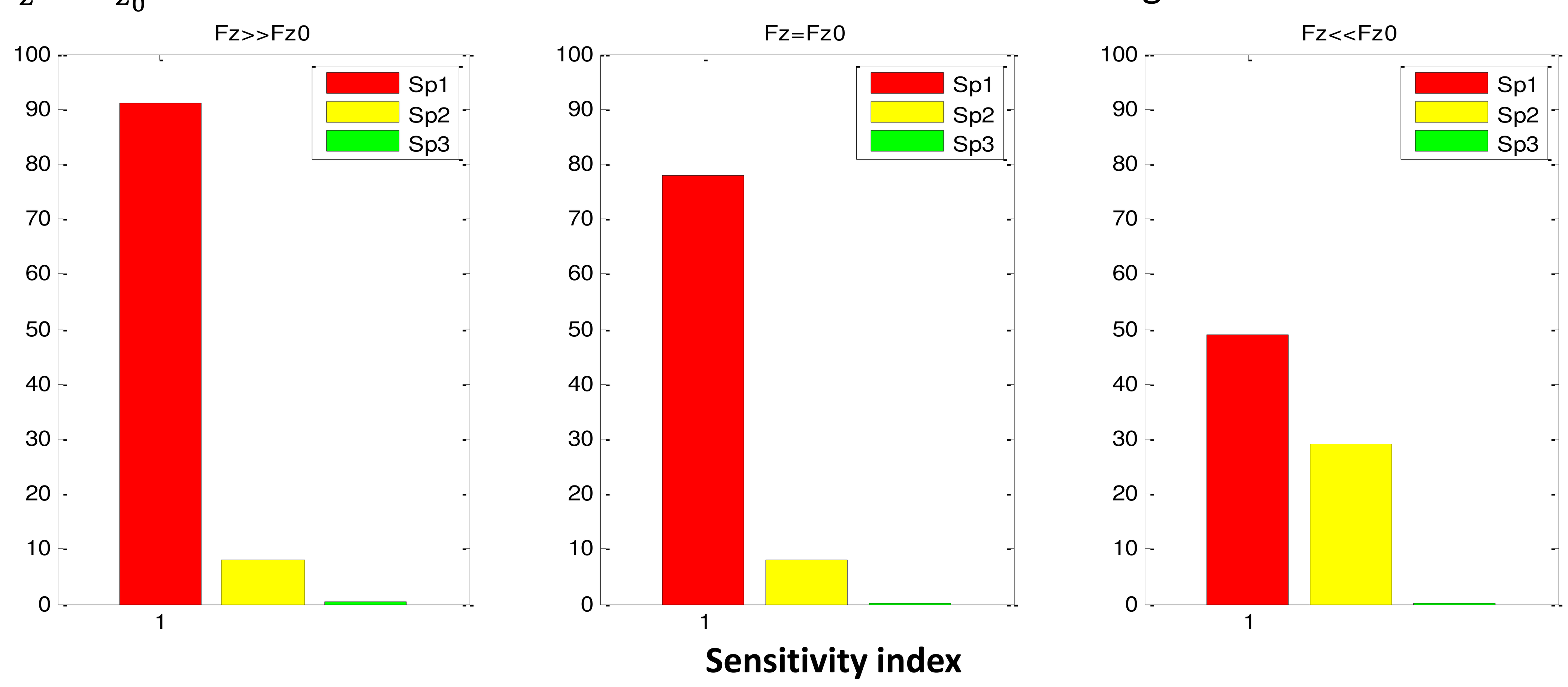
$$\widehat{S}_i = \frac{\sum_{j \in \Gamma_i} \hat{c}_j^2 E\left(\psi_j^2(u_i)\right)}{\sum_{j=1}^{M} \hat{c}_j^2 E\left(\psi_j^2(u_1, \cdots, u_n)\right)}$$

Where :

- M is the number of PC coefficients.
- n is the number of parameters.
- $\psi_j(\mathrm{u})$ is a multidimensional orthogonal polynomials.

4. Results

- $F_z = F_{z_0}$: Situation without acceleration or braking.
- $F_z \gg F_{z_0}$: Braking situation for tires of the front axle or acceleration for tires of the rear axle.
- $F_z \ll F_{z_0}$: Acceleration situation for tires of the front axle or braking for tires of the rear axle.



- Spi: Sensitivity index corresponding to parameter $\boldsymbol{\theta_i}$

5. References

[1] H. B. Pacejka. Tyre and Vehicle Dynamics. Elsevier, 2006.

[2] S. Hamza, A. Birouche, F. Anstett-Collin and M. Basset. Sensitivity analysis for the study of a tire model with correlated parameters and an arbitrary distribution. *International Conference on Sensitivity Analysis of Model Output*, Nice, France, 1-4 July, 2013.

[3] G. Blatman, B. Sudret, Sparse polynomial chaos expansion and adaptive stochastic finite element using a regression approach, Comptes rendus de Mecanique 336 (6) (2008) 518-523.