Sensitivity analysis of tire model micro-coefficients

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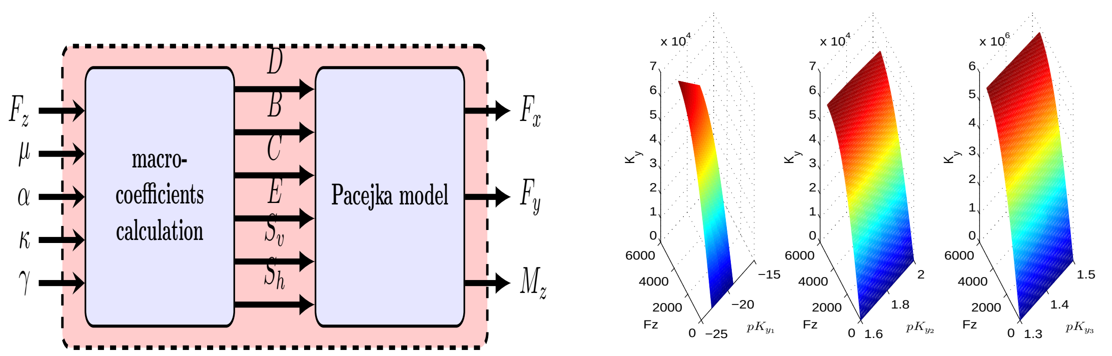
Problem statement

Tires involve the vehicles' 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. 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. An overview of Pacejka tire model is given in Fig. 1(a) :



(a) (b)

Fig. 1 – (a) An overview of the structure of Pacejka tire model (b) Graphical representation of lateral stiffness Ky as a function of vertical load F_z and micro-coefficients pKy_1, pKy_2 and pKy_3

Input variables are the vertical load F_z, the friction factor μ, the slip angle α and the camber angle γ. The coefficients B, C, D, E, S_h and S_v are the macro-coefficients which depend of the set of parameters called micro-coefficients. The outputs of the model are the longitudinal tire force F_x, the lateral tire force F_y and the tire self-aligning moment M_z. In [2], it has been shown that the lateral stiffness K_y and the slip angle α are the parameters affecting the lateral force variation. However, the lateral stiffness K_y depends on numerous parameters. In Fig. 1(b) the lateral stiffness Ky is illustrated as a function of the vertical load F_z and the micro-parameters pKy_1, pKy_2 and pKy_3 in their entire range of variation. Through Fig. 1(b), one can observe that the lateral stiffness increases when the vertical load increases. The impact of pKy_1, pKy_2 and pKy_3 on the lateral stiffness cannot be clearly distinguished. Thus, this work is an extension study of parameters influence of Pacejka tire model [1,2]. The aim is to quantify the influence of micro-parameters pKy_1, pKy_2 and pKy_3 on the lateral stiffness Ky and, therefore, on F_y.

Method and result

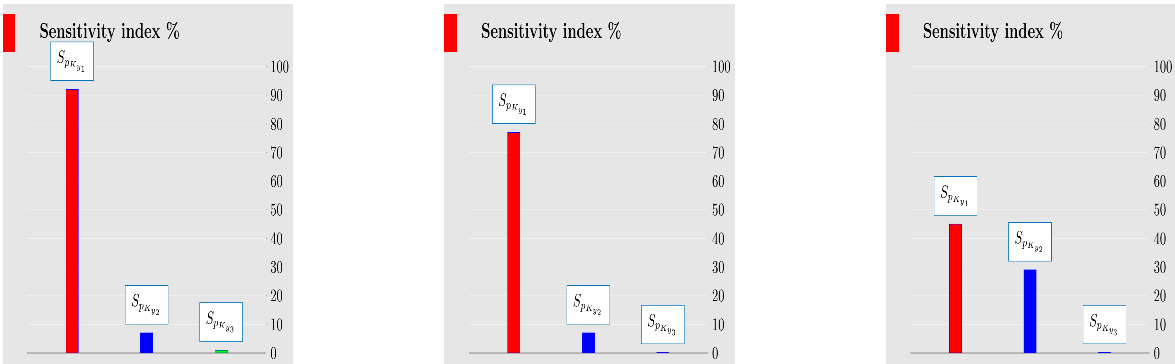
Polynomial chaos approach (PC) as a global sensitivity analysis method is applied. This method consists of approximate Ky into a sum of PC as follows [4]:

$$Ky \approx \sum_{j=0}^{\infty} c_j \psi_j(pKy_1, pKy_2, pKy_3) \tag{1}$$

with c_j the unknown deterministic coefficients and ψ_j the multi-variate orthonormale polynomial basis for (pKy_1, pKy_2, pKy_3) including all cross-terms between different parameters.
Since the lateral stiffness Ky depends on the vertical load F_z, this study has been made during different situations and for a small value of slip angle α. Depending on the value of F_z, three cases are considered :

- $F_z = F_{z_0}$: corresponding to situation without acceleration or braking.
- $F_z >> F_{z_0}$: corresponding to braking situation for tires of the front axle or acceleration for tires of the rear axle.
- $F_z << F_{z_0}$: corresponding to acceleration situation for tires of the front axle or braking for tires of the rear axle.

Sensitivity index of micro-parameters for different values of vertical load F_z are given in Fig. 2.



(a) $F_z >> F_{z_0}$ (b) $F_z = F_{z_0}$ (c) $F_z << F_{z_0}$

Fig. 2 – Sensitivity index

This result highlights the contribution of parameter pKy_1 on the lateral stiffness Ky variation for hight values of vertical load $F_z >> F_{z_0}$ and a negligible influence of other parameters. However, the parameter pKy_2 become influent when $F_z << F_{z_0}$.

References

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Short biography – The objective of this thesis is to develop approaches for global sensitivity analysis for dynamic models. These approaches will be applied in the automobile domain.