A Method to Combine an MBD Tire Model with a Thermo-dynamical one to improve the accuracy in the tire simulations

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ABSTRACT

Current state-of-the-art tire models may show a certain lack of accuracy in some advanced handling applications. This lack of accuracy is partly due to thermal effects. In reality, the tire rubber temperature can dramatically increase under certain conditions. The tire friction coefficient strongly depends on the temperature level. As a direct consequence of the temperature variations, the tire's handling performance changes, e.g. when the temperature significantly differs from its optimal value, the tire's grip level declines. As a result, the vehicle's longitudinal and lateral behavior is influenced.

This paper shows that in order to increase the reliability of the tire models also in the described extreme conditions, it is necessary to couple a thermo-dynamical model with a mechanical one. The thermal model is important to estimate the temperature propagation inside the tire structure and the temperature evolution over time. It is shown how propagation and evolution is the result of a dynamic energy equilibrium between phenomena of different natures: heat is generated in areas with large cyclic deformations due to the energy dissipated from the rubber strains and in the sliding part of the contact patch due to sliding friction. The rubber cools down because energy is transferred to the air (internally and externally) and to the asphalt in the stick zone of the contact patch.

The described thermal model is designed to be used as a module and is applicable to tire models of various modeling details. In this paper, the coupling with an enhanced Magic Formula and with the detailed structural MBD tire model CDTire/3D are shown. The coupling strategy is more physical and direct in the case of the structural model, because of the local nature of this model. In fact, the energy input for the thermal model is calculated by using the tire structural model for each point of the tire structure volume. On the other hand, the structural model behavior is influenced by the locally calculated temperature by modifying the local structural properties such as shell dampings, stiffness's and the local friction coefficient of the tread/asphalt contact. In the case of the Magic Formula, one challenge is to model the temperature creation and also the temperature transfer to the environment and also the temperature influence back to the Magic Formula itself, because of the missing physicality of the model.

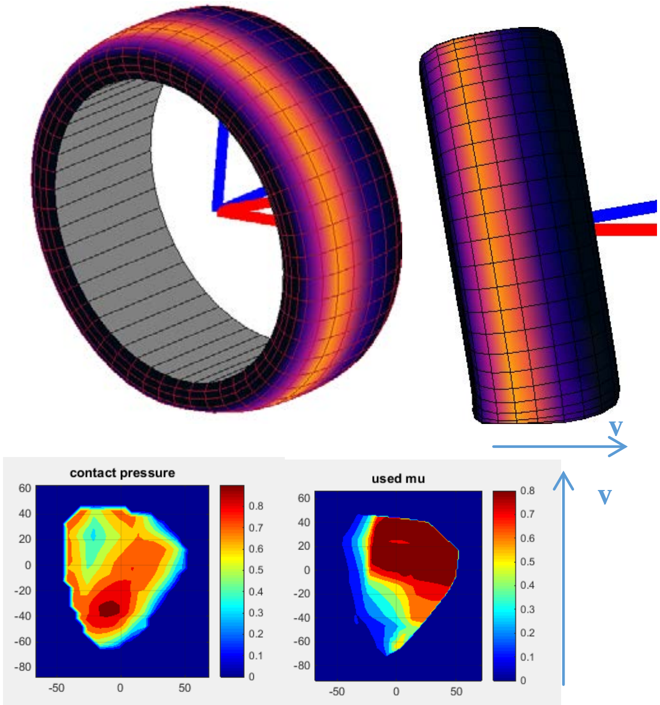

Figure 1 .CDTire/3D with thermal coupling .On the top a snapshot of a cornering scenario (Slip angle 0.3) for an Ortho and longitudinal view. In the bottom picture the contact pressure distribution and the local used friction coefficient contours for the dynamic contact patch.

At the end of the paper, the capabilities of the overall models are demonstrated and qualified in some illustrative tire and vehicle simulation scenario. The validation of the overall model will be shown using measured data from Formula 1.

Keywords: Thermodynamic, tire, flexible ring, vehicle dynamics, handling, NVH, comfort, safety

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