An analytical model of dissipated viscous and hysteretic energy due to interaction forces in a pneumatic tire: Theory and experiments

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ABSRACT

When in use, a tire dissipates energy according to various mechanisms: rolling resistance, viscosity, hysteresis, friction energy, etc. This dissipation of energy contributes to influencing tire temperature, contact conditions and the resulting friction coefficient.

This research project deals with viscoelastic and hysteretic mechanisms, and presents an explicit expression of the energy dissipated by tire–road interactions caused by these mechanisms. It is based on the Dahl model with regard to the hysteretic force together with a spring and a frequency variable damping coefficient with regard to the viscoelastic one. The energy expression found in this way can be used in tire thermal models to determine one of the heat flows needed to estimate the contact temperature and to find out the actual friction coefficient to be used in real time tire–road interaction models.

Experimental tests were carried out, for longitudinal interaction only, in order to evaluate the effectiveness of the proposed expression by identifying the parameters and validating the results.

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1. Introduction

In the field of vehicle dynamics and tire–road interaction in particular, an evaluation of the energy dissipated inside the tire is particularly interesting because it affects the contact temperature and consequently the friction conditions.

Tire–road interaction forces develop inside the contact zone [1]. During tire use, these forces generate cyclic stress conditions whose frequency depends on the wheel rotational speed. This cyclic stress produces energy dissipation connected to the structure and the materials used [2].

The dissipated energy has at least a double negative effect: first of all, it is related to the rolling resistance [3], and second, it causes a strong local raise in temperature in the contact patch, above all due to the low diffusivity of rubber.

This warming strongly affects the behavior of the elastomer by altering the adherence coefficient and, as a result, the interaction between tire and road.

There are several studies in the literature, which characterize and attempt to quantify tire energy dissipation by means of finite elements models [4], requiring long computation time.

An analytical model of the energy dissipated by a pneumatic tire is proposed in this work. A model of this type can be used in tire thermal models [5] to determine one of the heat flows required to estimate the contact temperature and to find out the actual friction coefficient to be used in physical models of tire–road interaction [6]. In this way, the effects of dissipated energy on the dynamics of the whole vehicle can be evaluated.