
A periodic Semi Analytical Method (SAM) for the tire pavement contact

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Abstract

Since the early 2010s, the weight of individual vehicles is increasing as electric-power technologies are favored of combustion-powered engines; especially due to heavy batteries built to meet large autonomy requirements. This results in higher stress and wear at the tire pavement interface, for instance leading to increased fine particles emissions (1). From a tire manufacturers perspective, the transition to new materials formulation also influences tire/pavement contact. To predict the tire performances, models and simulation tools of contact mechanics are developed to estimate the interaction between the rubber material and the rough surface.

However, this physics is challenging to model. In fact, its complexity comes from two different aspects of the problem: the viscoelastic behavior of the tire and the multi-scale roughness of the road. On the one hand, a tire is made of a non-linear viscoelastic rubber material filled with aggregates of silica and carbon. The amount and composition of such rigid inclusions in the elastomer matrix drastically change the materials properties and can make it even more non-linear (2). On the other hand, a road is a complex multi-scale rough surface that needs fine discretization to be properly modelled.

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In addition, the time-dependency of the material behavior, combined with the different scales of the rough surface to consider constitutes the major numerical challenge. The Finite Element Method (FEM) is disregarded in this context as computation time could quickly skyrocket with the required time and spatial discretizations. Semi-Analytical Method (SAM) however offers significant cost reduction because only the meshing of the surface is needed: the response in the bulk being given by the Boussinesq solutions. Hence considering a complex viscoelastic material and some detailed multi-scale surfaces can be computed at reasonable costs (3).

Existing in-house developed SAM code solves the contact problem as a minimization of the enthalpy of the considered system, which is equivalent to the minimization of the gap between the two surfaces in contact. The contact problem is solved with a Conjugate Gradient Method (CGM), where the displacements are computed thanks to dedicated Fast Fourier Transform (FFT) algorithms.

To apply this method to our study (viscoelastic solid sliding on a multi-scale rough surface), we first implemented a periodic way to solve the contact problem. One of our hypotheses is that the road could be represented as a cyclic load of the same representative portion of the pavement applied to a viscoelastic slab (2,4). This periodic behavior is embedded within the CC-FFT (Continuous Convolution FFT) technique, where the periodicity is computed exclusively in the Fourier space (5). The viscoelasticity of the material is represented with a linear model, using elastic/viscoelastic correspondence of the contact problem with the introduction of the creep function (6). The resulting numerical tool is formulated both in the transient and steady-state regimes as in (7).

Our formulation can therefore predict an apparent friction coefficient of a given linear rubber material sliding on a rough surface, computed from the hysteric-driven asymmetry of the pressure distribution, without considering any Coulomb friction nor adhesion (neglected for now) at the tire/pavement interface. The evolution of this apparent friction coefficient is analyzed with respect to the periodicity and multi-scale characteristics of the rough surface and some relevant regimes are exhibited with analytical surfaces and realistic pavement reproductions.

Research in progress is focused on including non-linear viscoelastic effects in the material's description, to fit with experimental campaigns run on tire.

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