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Comparison of the Arbitrary Lagrangian Eulerian and the Total Lagrangian formulation in Rolling Contact Tire Simulations

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Contact forces induced by the road are a major excitation source of a rolling tire and can lead to significant interior noise [1]. Finite Element (FE) analysis with contact is therefore key to assess various tire designs. However, currently tire simulation literature is predominantly limited to the use of the Arbitrary Lagrangian Eulerian (ALE) formulation, only feasible for axisymmetric tires [2]. As a result, it is difficult to assess the impact of e.g. the tread pattern on the contact conditions and vibrational excitation. To overcome this limitation the Total Lagrangian (TL) formulation can be employed, wherein the mesh actually rotates.

In this work, we will present a TL framework for rolling contact tire simulations and compare this to a reference ALE model with respect to the resulting contact solutions and the overall tire behavior for dynamic simulations.
The ALE formulation splits the deformation into a pure rigid body motion and the deformation around the rotated reference configuration. Therefore the deformations are described in a Lagrangian way while the material flow, corresponding to the tire rotation, is expressed in an Eulerian description [2]. Within the TL formulation the reference configuration is the initial configuration, hence both material flow and deformations are described in a Lagrangian way [3]. In theory this TL description is more comprehensive, but a direct comparison for tires is missing in literature. A main point of attention in the TL formulation is to avoid contamination of the dynamic excitation through the spatial discretization in the rolling contact.

In this work, the examined system is a tire modelled with 3D volumetric elements in an in-house FE code including geometric and material nonlinearity. The rolling contact simulation is carried out on a rigid rough road surface. The system is solved in the time domain and the dynamic responses for both the ALE and TL approach are compared.

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