Analysis of nonlinear tire dynamics in high fidelity nonlinear Finite Element simulation

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Abstract. The dynamic behavior of tires is of great interest in the tire design process. Due to difficulties in acquiring experimental data (e.g. contact patch measurements) and the time consuming procedure of building prototypes, numerical models are needed. The nonlinear Finite Element Method is employed to accurately model the complex nonlinear structural behavior of tires. While the Arbitrary Lagrangian Eulerian formulation is predominantly used in literature, an alternative newly developed tire model based on the Total Lagrangian formulation is presented. It is shown that both formulations show similar results and that the influence of the excitation caused by the mesh in the Total Lagrangian formulation is limited. Furthermore, the influence of multiple modeling parameters on the dynamic response of the tire is investigated.

Introduction

Tires are a major noise emission source, especially for electric vehicle, and can lead to significant interior and exterior noise. The noise emission originates from the dynamic vibrations of the tire, where the main excitation source of the tire is the tire/road interaction [1]. To properly asses the structural behavior of tires to optimize the design for noise emission, fuel consumption or handling, accurate models are required in the process. The need for numerical models is caused by the inaccessibility of certain measurement quantities such as displacement in the contact patch and the time consuming procedure of prototyping and testing. Due to the present geometric, material and rolling contact nonlinearity accurate, predictive Finite Element (FE) tire modelling poses a challenge. In literature predominantly the Arbitrary Langrangian Eulerian (ALE) formulation is used [2,3], but the ALE formulation is only applicable to axisymmetric tires. By using a TL formulation for the tire model an arbitrary tire and tread geometry can be assessed. In theory the TL description [4] is more comprehensive, but a direct comparison for tires is missing in literature.

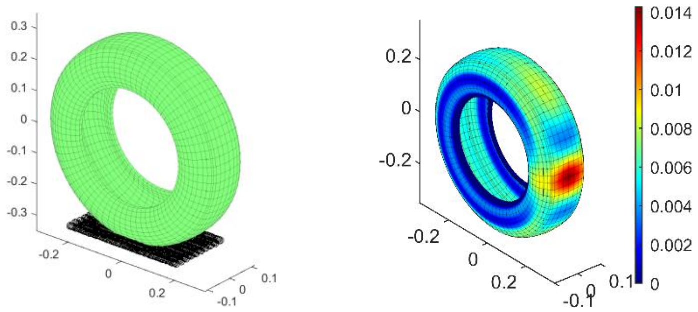

Figure 1: Total Lagrangian tire model mesh and dynamic deformation

Results and Discussion

The main disadvantages of the ALE formulation are limitations in tire geometry (e.g. detailed tread patterns) and difficult treatment of viscoelastic material behavior. While these drawbacks are resolved by the use of the TL formulation, the main challenge is to limit the contamination of the dynamic excitation caused by the spatial discretization of the TL FE model (see Figure 1). This excitation is generated by the actual rotation of the mesh in the TL formulation as opposed to the stationary mesh in the ALE formulation, where the rotation is described in an Eulerian way.

In this work, the tire model is created by the use of 3D volumetric elements in an inhouse FE code including geometric and material nonlinearity. A time domain simulation of the tire model interacting with a rigid road profile is carried out for both formulations. The dynamic behavior of the tire in both cases is compared. It is shown that the TL formulation yields equivalent results as the ALE formulation and the excitation caused by the mesh is limited. Furthermore, the parameter influence of the modelling parameters (e.g. road roughness, material parameters or speed dependence) on the vibrational behavior is analyzed.

References

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