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Issues in Tire-Pavement Contact Modelling

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1 INTRODUCTION

Despite careful planning and design of infrastructure projects as well as quality checks during the construction, every year a considerable amount of damage occurs to the road network. These damages lead to a high risk for traffic, significant cost for maintenance and repair as well as to an environmental impact due to congestion and traffic diversion.

In order to assess the sensitivity of asphalt pavements with respect to damage, fundamental knowledge about the material behaviour of asphalt and especially the interaction of tires and pavements is required. By means of numerical models, the efficient prediction of damage and life cycle of pavements becomes possible. These models allow a realistic mapping of the structural behaviour of tires and pavement as well as the consideration of temperature and stress dependent behaviour of tire and pavement materials.

In the scientific literature, no complex three-dimensional and coupled modelling of the tire-pavement-system has been reported so far. Usually, one of the components, either pavement or tire, is strongly simplified. Thus, the outcome of the investigation is limited according to the modelling constraints. These restrictions shall be overcome by current research work. For the first time, a realistic sensitivity study for both subsystems leading to the relevant influence factors can be achieved. A structural understanding of the mechanics of the coupled system will be developed which will give insight into detailed parts of the subsystems. The mechanical impact of tires on pavements is usually modelled as a spatially stationary load distributed over a certain contact area. To eliminate the drawbacks associated with a simplified modelling of the pavement loading, it is aimed to use an Arbitrary Lagrangian Eulerian (ALE) formulation for the tire as well as for the pavement structure. This formulation permits to use finite element (FE) models for pavements that are based on a Lagrangian approach, and requires additionally an Eulerian formulation to account for the relative displacement between tire and pavement materials during rolling of the tire.

Relevant model parameters will be determined by means of material tests. The coupled model will be verified against field measurements of tire-pavement interaction.

2 NUMERICAL MODELLING OF TIRES AND PAVEMENTS

2.1 *Recent progress in the field of tire simulation*

In the past years, numerical simulations of air filled tires for passenger cars, trucks and airplanes - using FE methods - have reached a very high accuracy level. Due to the recent increase in computational power, it is feasible to analyse fine meshed structures that are subjected to com-

plex load-scenarios and exhibit nonlinear material behaviour. In order to obtain reliable results from the numerical simulation, all components of the tire are represented. In the contact area between tire and pavement surface, the FE mesh is usually very dense while the rest of the tire is modelled much coarser. The loading of the tire at steady state rolling can be captured by an ALE formulation. With the help of this formulation, it is possible to simulate driving maneuvres like free rolling, cornering, accelerating and braking. The nonlinear elastic material behaviour of the tire is depicted by constitutive laws that account for large strains. Anisotropy due to fibre-reinforcements is also considered within these constitutive approaches.
Several research projects which have been conducted recently focused on phenomena occurring in the contact area of the tire and the pavement surface. Goal of the research was a more accurate formulation of the vertical and tangential contact stresses as well as an improved modelling of the friction between tire and pavement surface. Within the mentioned research, however, the pavement has been modelled as being rigid. Only very few research projects focused on rolling tires acting on a flexible pavement. In this context, emphasis has been placed on the effects of the flexible pavement on the tire just as boundary conditions. The influence of the more accurate formulation of the tire on the pavement was not investigated so far.

2.2 *Recent progress in the field of pavement simulation*

During recent years, enormous experimental and theoretical effort has been undertaken to develop computational models that capture the complex bearing behaviour of pavements and pavement materials. One of the challenges in developing those models is to derive constitutive laws, based on thermo-dynamics, which take into account the nonlinear time-dependent behaviour of pavement materials. Moreover, an adequate consideration of the layered structure of pavements has been pursued. Numerical methods, as for example the method of FE, have successfully been applied to analyse pavement structures while satisfying the aforementioned challenges. Because of the complexity of the analysis involving cyclic loading, elasto-viscoplasticity, large deformations (of at least parts of the structures), utilization of the computational models require huge numerical capabilities.

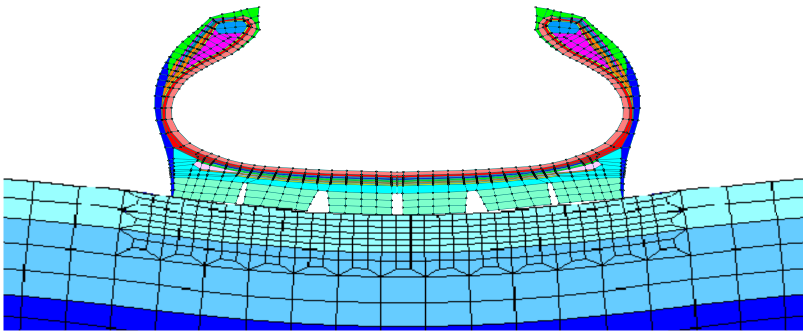

Figure 1: Cross-section of coupled model of tire-pavement system

3 MAIN GOALS OF TIRE-PAVEMENT CONTACT MODELLING

The main goals of the current research activities are summarized by the following topics:

- development of a coupled, efficient and physical simulation methodology for the system of tire and pavement,
- efficient and reliable structural analysis as well as prediction of the behaviour of the tire-pavement system for design and for development of codes,
- generation of mechanical understanding of the complex interactions of tire-pavement-systems,
- proposal of parameters for pavements and pavement materials with improved durability and less sensitivity to damage.