Modeling of the elastic tractive rolling contact for the prediction of pavement damage

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Abstract

Pavements are complex, multi-layered materials subjected to intricate loading conditions that lead to damage (1). As traffic moves over the road, various forms of degradation occur, and the renewal of pavements represents a significant global cost. Understanding the causes and evolution of this degradation is challenging, as both the road's behavior and the loads it experiences are difficult to model and predict.
A pavement consists of multiple layers with varying thicknesses and widely different elastic moduli. The magnitude of these layers is comparable to the contact size, making their influence crucial in determining the contact behavior. Additionally, temperature gradients throughout the day and across different seasons can cause the pavement's response to change. The velocity of passing loads introduces time-dependent behavior, a viscoelastic model may be necessary to account for. Lastly, while pavements are not homogeneous materials, this study assumes a continuous media.

On the loading side, several factors must be considered. First, the tire-pavement contact results in contact sizes similar to the thickness of the pavement layers. Moreover, the material properties of the contacting bodies are dissimilar, leading to complex interactions between normal and tangential behaviors. Furthermore, during acceleration, braking, or turning, a vehicle generates tangential forces or moments that are transmitted through the contact area. This tractive rolling situation results in complex contact conditions (2).

To address these challenges, a semi-analytical model for tractive rolling contact between dissimilar, multi-layered elastic materials is proposed. The model accounts for the behavior of the layered bodies by deriving influence coefficients for perfectly bounded layers of uniform thickness (3). The formulation is extended to include viscoelastic behavior, allowing the layers to have different properties and relaxation times. The normal and tangential problems are coupled and solved sequentially, enabling the consideration of transient contact behavior under transverse loads (4). This semi-analytical approach ensures a fast and robust solution, enabling the prediction of contact pressures, shear fields, and stresses within the body.

The model is applied to simulate a pavement subjected to a standard truck tire under various loading conditions, including pure rolling, acceleration, turnaround, and drift. The results highlight the significant impact of friction in the contact zone and show how different loading conditions lead to varied damage behaviors depending on the road configuration.

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These findings are crucial for road design, where only simple normal contact conditions are typically considered.

Finally, the results are compared to experiments from a full-scale traffic simulator on a real road, where deformations in the pavement's subsurface layers were measured. A very good agreement between the model and the experimental data was observed.

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