

Article

Dynamics Modeling and Suspension Parameters Optimization of Vehicle System Based on Reduced Multibody System Transfer Matrix Method

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Abstract: This study introduces an innovative vehicle-modeling framework based on the Reduced Multibody System Transfer Matrix Method, incorporating wheel–ground contact and friction to analyze dynamic performance metrics, including vertical acceleration, suspension deflection, and angular acceleration. The model is applied to simulate vehicle behavior at 40 km/h on Class D road conditions. To enhance dynamic characteristics, suspension parameters were optimized using the NSGA-II algorithm. The optimization process achieved significant reductions in vertical acceleration (24.12%), suspension deflection (25.98%), and angular acceleration (4.93%). The Pareto frontier facilitated the selection of a representative solution that balances smoothness, stability, and suspension performance. Frequency, PSD, and RMS analyses were performed under different road conditions and speeds to verify the robustness of the optimization results. The application of the transfer matrix method is extended to vehicle suspension modeling and optimization, offering valuable insights into improving ride comfort and stability. Additionally, it highlights the effectiveness of advanced multi-objective optimization techniques in improving vehicle dynamics and provides a robust methodology for practical applications.

Keywords: vehicle dynamics; transfer matrix method; NSGA-II; suspension optimization



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1. Introduction

The automotive industry is currently undergoing a period of transformation, primarily driven by digitalization, the principles of a circular economy, and sustainable development goals. Additionally, manufacturers are striving to address these challenges in an intensely competitive and rapidly evolving market environment. Against this backdrop, the intelligent manufacturing of the automotive sector has seen rapid development in recent years, facilitated by the application of CAE software [1]. This approach aims to evaluate the dynamic behavior of vehicles during the design, development, and prototyping phases. Compared to traditional experimental procedures, it helps reduce costs, shorten design and production timelines, and simultaneously maximize vehicle performance, comfort, environmental characteristics, quality, and safety.

The suspension system has consistently been a focal area of research within the field of vehicle dynamics. Comprising a set of rigid bodies capable of relative motion, the suspension system plays a crucial role in handling performance, stability, and comfort [2]. The function of a suspension system is to maximize the friction between the tires and the road surface, provide good steering stability, and ensure passenger comfort. Despite

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