

Modelling and Analysis of Vertical Vehicle Dynamics with Frequency-Dependent Suspension Properties for the Formula Student Electric Vehicle

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Formula Student (FS)

The internationally highly regarded engineering competition Formula Student (FS) challenges teams of students to design and build a formula racing car and compete against other universities in various disciplines. The various competitions offer an exceptional opportunity for students to apply their academic knowledge in a practical setting.

Introduction Bachelor-Thesis

Understanding the vertical dynamics of a Formula Student vehicle is crucial for optimizing both ride comfort and tire grip, two key factors that directly affect lap time and driver confidence. The suspension and tires act as a coupled dynamic system whose behaviour varies with excitation frequency, making it essential to account for frequency-dependent spring, damper, and tire characteristics in vehicle dynamics simulations.

This Bachelor Thesis focuses on the development and analysis of vertical vehicle dynamics models (quarter-, half-, and full-car configurations) that capture these effects. By modelling the interaction between suspension, damper, and tire dynamics, the project lays the foundation for future experimental validation and suspension tuning using dedicated test rigs such as the damper dyno or quarter-car rig.

Goal

The goal of this project is to develop and analyse mathematical models of the vertical vehicle dynamics of the Formula Student Electric Vehicle. The models will incorporate frequency-dependent spring, damper, and tire characteristics to accurately describe the car's vertical response to different road excitations. The findings will serve as a validated basis for future suspension optimization, controller design, and full-vehicle simulation.

Objectives:

- **Model Development:** Derive and implement linear and extended multi-degree-of-freedom vehicle models (quarter-, half-, and full-car).
- **Integration of Realistic Properties:** Include frequency-dependent and nonlinear spring and damper characteristics based on real or assumed data maps.
- **Dynamic Analysis:** Perform frequency and time domain analyses (natural frequencies, transmissibility, acceleration response, tire load variation).
- **Sensitivity Studies:** Investigate the influence of suspension stiffness, damping ratio, and tire stiffness on ride comfort and grip.
- **Validation Concept:** Develop a concept for validating the simulation results using future experimental data (e.g., damper dyno or quarter-car rig).

If you are interested in this project thesis, we kindly ask you to get in touch with us:

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