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Vehicle Dynamics

Fundamentals and Ultimate Trends

Springer

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Preface

Since the invention of the world's first motor vehicle, more than 100 years ago, automobiles have been widely accepted in our society with the progress of modern industry. The study and understanding of vehicle dynamics have always played a crucial role in the design of vehicles, with the aim of guaranteeing safety and stability as well as good performance. The recent advent of electric vehicles and the future perspective of widespread autonomous cars have posed further interesting challenges for the vehicle dynamicist. Nonetheless, the importance of the basics should never be underestimated—after all, essentially a vehicle behaviour is described by second Newton's law, $F = ma$.

With these motivations, an international course was organised at CISM in 2019, with a team of lecturers including two eminent academics, two experienced researchers, and two industrial representatives. The aim of this book—which collects contributions from the lecturers—is to recall the fundamentals of vehicle dynamics and to present and discuss the state of the art of ultimate trends in the field, including torque vectoring control, vehicle state estimation, and autonomous driving.

The first chapter, "Fundamentals on Vehicle and Tyre Modelling", discusses the equations of motion for a generic vehicle, including roll and pitch dynamics as well as the vertical travel of the sprung mass. Then, the chapter deals with the fundamentals of tyre modelling, with a detailed analysis of the existing tyre models. Finally, a new linear tyre model with varying parameters is presented, which is at the same time simple—which makes it suitable for control purposes—and accurate in that it represents combined tyre-road interactions (longitudinal and lateral).

The second chapter, "Vehicle Steering and Suspension Kinematics/Compliance and Their Relationship to Vehicle Performance", is dedicated to the analysis of the key peculiarities of vehicle steering and suspension systems. After looking into tyre behaviour, the chapter dives into wheel end architecture and suspension kinematics, with the analysis of the suspension design parameters (camber, caster, kingpin, etc.) and their effects on vehicle behaviour, together with suspension compliance. Steering kinematics and compliance are discussed, along with the relationships between weight transfer, kinematics, and compliance. The final part deals with the interesting concept of tyre utilisation.

In the third chapter, "Tyre Mechanics and Thermal Effects on Tyre Behaviour", the structure of the tyre and the mechanisms involved in tyre-road interaction are analysed. The effect of temperature on the tyre behaviour is then examined. Detailed thermal models are presented, accounting for heat generation—due to both the tyre-road tangential interactions and the tyre cyclic deformation during rolling—and heat exchange at different levels. Finally, the chapter discusses the factors involved in tyre wear and the different approaches proposed so far to model it.

The second part of the book, devoted to ultimate trends in vehicle dynamics, begins with the chapter "Torque Vectoring Control for Enhancing Vehicle Safety and Energy Efficiency". The chapter first presents the principle of torque vectoring and the general framework of a torque vectoring system. Different approaches to define the vehicle reference yaw rate and reference sideslip angle are compared, with a focus on the design of the full vehicle cornering response and the definition of driving modes selectable by the driver. Various control methodologies and torque distribution strategies are discussed, along with their implications for vehicle safety and energy efficiency.

After introducing the motivations for the need of state estimators, the fifth chapter, "State and Parameter Estimation for Vehicle Dynamics", presents an accurate analysis of the principles of observers and estimators and the methods to implement them. The well-known Kalman filter is contextualised and presented with rigour, together with its variants. The important concept of observability is dealt with, including its physical interpretation and the support of enlightening examples. A specific estimation methodology is discussed in detail, able not only to estimate relevant vehicle states (such as the sideslip angle), but also tyre parameters.

The sixth chapter, "Automated Driving Vehicles", is dedicated to the future of vehicles: autonomous driving. After an introduction on the role of the driver, the chapter discusses the key aspects of sensor fusion, including typical sensor characteristics and requirements, and how to use them to obtain a reliable representation of the environment. Assuming the availability of such representation, the problem of motion planning is dealt with, resulting in the desired driving path and speed profile. Then, the chapter discusses control techniques for the vehicle to follow the desired path and to track the desired speed profile. Finally, verification, validation, and safety issues are addressed.

I would like to thank all the authors for their precious contributions. I trust this book will be a valid resource for graduate students and researchers in the field of vehicle dynamics and control.

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