1. Tyre Characteristics and Vehicle Handling and Stability
   1.1. Introduction
   1.2. Tyre and Axle Characteristics
      1.2.1. Introduction to Tyre Characteristics
      1.2.2. Effective Axle Cornering Characteristics
   1.3. Vehicle Handling and Stability
      1.3.1. Differential Equations for Plane Vehicle Motions
      1.3.2. Linear Analysis of the Two-Degree of Freedom Model
      1.3.3. Non-Linear Steady-State Cornering Solutions
      1.3.4. The Vehicle at Braking or Driving
      1.3.5. The Moment Method
      1.3.6. The Car-Trailer Combination
      1.3.7. Vehicle Dynamics at More Complex Tyre Slip Conditions

2. Basic Tyre Modelling Considerations
   2.1. Introduction
   2.2. Definition of Tyre Input Quantities
   2.3. Assessment of Tyre Input Motion Components
   2.4. Fundamental Differential Equations for a Rolling and Slipping Body
   2.5. Tyre Models (Introductory Discussion)

3. Theory of Steady-State Slip Force and Moment Generation
   3.1. Introduction
   3.2. Tyre Brush Model
      3.2.1. Pure Side Slip
      3.2.2. Pure Longitudinal Slip
      3.2.3. Interaction between Lateral and Longitudinal Slip
      3.2.4. Camber and Turning (Spin)
   3.3. The Tread Simulation Model
   3.4. Application: Vehicle Stability at Braking up to Wheel Lock

4. Semi-Empirical Tyre Models
   4.1. Introduction
   4.2. The Similarity Method
      4.2.1. Pure Slip Conditions
      4.2.2. Combined Slip Conditions
      4.2.3. Combined Slip Conditions with $F_x$ as Input Variable
   4.3. The Magic Formula Tyre Model
      4.3.1. Model Description
      4.3.2. Full Set of Equations
      4.3.3. Extension of the Model for Turn Slip
      4.3.4. Ply-Steer and Conicity
      4.3.5. The Overturning Couple
      4.3.6. Comparison with Experimental Data for a Car Tyre and for a Truck Tyre

5. Non-Steady-State Out-of-Plane String-Based Tyre Models
   5.1. Introduction
   5.2. Review of Earlier Research
   5.3. The Stretched String Model
      5.3.1. Model Development
      5.3.2. Step and Steady-State Response of the String Model
      5.3.3. Frequency Response Functions of the String Model
   5.4. Approximations and Other Models
      5.4.1. Approximate Models
      5.4.2. Other Models
   5.5. Tyre Inertia Effects
      5.5.1. First Approximation of Dynamic Influence (Gyroscopic Couple)
      5.5.2. Second Approximation of Dynamic Influence (First Harmonic)
   5.6. Side Force Response to Time-Varying Load
      5.6.1. String Model with Tread Elements Subjected to Load Variations
      5.6.2. Adapted Bare String Model
      5.6.3. Force and Moment Response

List of Chapters:

1. Tyre Characteristics and Vehicle Handling and Stability
2. Basic Tyre Modelling Considerations
3. Theory of Steady-State Slip Force and Moment Generation
4. Semi-Empirical Tyre Models
5. Non-Steady-State Out-of-Plane String-Based Tyre Models
6. Theory of the Wheel Shimmy Phenomenon
   6.1. Introduction
   6.2. The Simple Trailing Wheel System with Yaw Degree of Freedom
   6.3. Systems with Yaw and Lateral Degrees of Freedom
   6.4. Shimmy and Energy Flow
      6.4.1. Unstable Modes and the Energy Circle
      6.4.2. Transformation of Forward Motion Energy into Shimmy Energy
   6.5. Non-Linear Shimmy Oscillations

7. Single Contact Point Transient Tyre Models
   7.1. Introduction
   7.2. Model Development
      7.2.1. Linear Model
      7.2.2. Semi-Non-Linear Model
      7.2.3. Fully Non-Linear Model
      7.2.4. Non-Lagging Part
      7.2.5. The Gyroscopic Couple
   7.3. Enhanced Non-Linear Transient Tyre Model

8. Applications of Transient Tyre Models
   8.1. Vehicle Response to Steer Angle Variations
   8.2. Cornering on Undulated Roads
   8.3. Longitudinal Force Response to Tyre Non-Uniformity, Axle Motions and Road Unevenness
      8.3.1. Effective Rolling Radius Variations at Free Rolling
      8.3.2. Computation of the Horizontal Longitudinal Force Response
      8.3.3. Frequency Response to Vertical Axle Motions
      8.3.4. Frequency Response to Radial Run-Out
   8.4. Forced Steering Vibrations
      8.4.1. Dynamics of the Unloaded System Excited by Wheel Unbalance
      8.4.2. Dynamics of the Loaded System with Tyre Properties Included
   8.5. ABS Braking on Undulated Road
      8.5.1. In-Plane Model of Suspension and Wheel/Tyre Assembly
      8.5.2. Anti-Lock Braking Algorithm and Simulation

9. Short Wavelength Intermediate Frequency Tyre Model
   9.1. Introduction
   9.2. The Contact Patch Slip Model
      9.2.1. Brush Model Non-Steady-State Behaviour
      9.2.2. The Model Adapted to the Use of the Magic Formula
      9.2.3. Parking Manoeuvres
   9.3. Tyre Dynamics
      9.3.1. Dynamic Equations
      9.3.2. Constitutive Relations
   9.4. Dynamic Tyre Model Performance
      9.4.1. Dedicated Dynamic Test Facilities
      9.4.2. Dynamic Tyre Simulation and Experimental Results

10. SWIFT and Road Unevennesses
    10.1. Dynamic Tyre Response to Short Road Unevennesses
         10.1.1. Tyre Envelopment Properties
         10.1.2. The Effective Road Plane
         10.1.3. The Two-Point Follower Technique
         10.1.4. The Effective Rolling Radius when Rolling over a Cleat
         10.1.5. Simulations and Experimental Evidence
         10.1.6. Effective Road Plane and Road and Wheel Camber
    10.2. Three Advanced Dynamic Tyre Models: SWIFT, FTire, RMOD-K

11. Motorcycle Dynamics
    11.1. Introduction
    11.2. Model Description
         11.2.1. Geometry and Inertia
         11.2.2. The Steer, Camber and Slip Angles
         11.2.3. Air drag, Driving or Braking, Fore and Aft Load Transfer
         11.2.4. Tyre Force and Moment Response
    11.3. Linear Equations of Motion
    11.4. Stability Analysis and Step Responses
11.5. Analysis of Steady-State Cornering
   11.5.1. Linear Steady-State Theory
   11.5.2. Non-Linear Analysis of Steady-State Cornering
   11.5.3. Modes of Vibration at Large Lateral Accelerations

11.6. Motorcycle Magic Formula Tyre Model
   11.6.1. Full Set of Tyre Magic Formula Equations
   11.6.2. Measured and Computed Motorcycle Tyre Characteristics

12. Tyre steady-state and dynamic test facilities

References

List of Symbols

Appendix 1. Sign Conventions for Force and Moment and Wheel Slip

Appendix 2. TreadSim

Appendix 3. SWIFT Parameters
   App.3.1. Parameter Values of Magic Formula and SWIFT Model
   App.3.2. Non-Dimensionalisation
   App.3.3. Estimation of SWIFT Parameter Values

Index

Exercises

Exercise 1.1. Construction of effective axle characteristics at load transfer
Exercise 1.2. Four-wheel steer, condition that vehicle slip angle vanishes
Exercise 1.3. Construction of the complete handling diagram from pairs of axle characteristics
Exercise 1.4. Stability of a trailer
Exercise 2.1. Slip and rolling speed of a wheel steered about a vertical axis
Exercise 2.2. Slip and rolling speed of a wheel steered about an inclined axis (motorcycle)
Exercise 2.3. Partial differential equations with longitudinal slip included
Exercise 3.1. Characteristics of the brush model
Exercise 4.1. Assessment of off-nominal tyre side force characteristics and combined slip characteristics with $F_x$ as input quantity
Exercise 4.2. Assessment of force and moment characteristics at pure and combined slip using the Magic Formula and the similarity method with $\kappa$ as input
Exercise 5.1. String model at steady turn slip
Exercise 6.1. Influence of the tyre inertia on the stability boundary
Exercise 6.2. Zero energy circle applied to the simple trailing wheel system
Exercise 7.1. Wheel subjected to camber, lateral and vertical axle oscillations
Exercise 8.1. Response to tyre stiffness variations
Exercise 8.2. Self-excited wheel hop