

Fortschritt-Berichte VDI

Reihe 12

Verkehrstechnik/
Fahrzeugtechnik

Dipl.-Ing. Christian Knobel,
München

Nr. 696

Optimal Control Allocation for Road Vehicle Dynamics using Wheel Steer Angles, Brake/Drive Torques, Wheel Loads and Camber Angles

Technische Universität Darmstadt
FG Fahrzeugtechnik

**Inventarnummer:
1859**



Berichte aus dem
Institut für
Robotik und Mechatronik

Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Contents

Notations and Abbreviations	vii
1 Introduction	1
1.1 The Influencing Variables of Vehicle Dynamics	2
1.2 State of Research	3
1.3 Structure of this Thesis Work	4
2 Vehicle and Tire Modeling	6
2.1 Tire Force Model	6
2.2 Multi-Body Vehicle Model	8
2.3 Planar Vehicle Model	13
2.4 Summary	15
3 Optimized Force Allocation - New Approach for Vehicle Dynamics Control	17
3.1 Introduction and Applications of Force Allocation	17
3.2 Boundaries of the System Planar Vehicle Motion	20
3.3 Inversion of the Planar Vehicle Model	22
3.4 Objectives to Optimize the Force Allocation	29
3.5 Design Parameters for the Optimization of the Force Allocation	34
3.6 Used Constraints for the Optimization	36
3.7 Summary	37
4 Comparison of Configurations for Available Actuators	39
4.1 Selection of Configurations of Available Actuators	39
4.2 Definition of the Driving Maneuver	42
4.3 Benchmark Criteria	43
4.4 Analysis of Actuator Configurations	43
4.5 Summary	49
5 Investigation of the Actuator Dynamics	51
5.1 Actuator Kinematics with and without Limits	51
5.2 Influence of Actuator Kinematic Variations on the Planar Vehicle Motion	55
5.3 Summary	61
6 Impact of Actuator Failures on Vehicle Dynamics	64
6.1 Maneuver and Failing Strategy for Steering Actuator Failure	64
6.2 Maneuver and Failing Strategy for Brake Actuator Failure	65
6.3 Steering and Brake Actuator Failure Analysis	65
6.4 Summary	72

7 Force Transfer in the Tire Contact Patch	73
7.1 Causes of the Camber Angle	73
7.2 General Influence of Camber Angle on Conventional Tires	74
7.3 Influence of the Camber Angle on the Maximum Lateral Force	75
7.4 Optimal Camber Angle	77
7.5 Summary	78
8 Influence of Force Transfer on the Planar Vehicle Motion	79
8.1 Parameter Variations for the Analysis	79
8.2 Driving Maneuvers and Benchmark Criteria	79
8.3 Analysis of the Driving Maneuver	80
8.4 Summary	86
9 Conclusion	88
9.1 How can the Control of Vehicle Dynamics be accomplished in an Optimal Fashion?	88
9.2 Which Influencing Variables should be actuated in order to enhance Vehicle Dynamics?	89
9.3 Which actuators for Influencing Variables should be improved to optimize Vehicle Dynamics?	90
9.4 Outlook	90
9.5 Main Contribution of this Thesis	91
Appendix	92
A Solving of the Optimization Approaches	93
A.1 The Solving Algorithm Sequential Quadratic Programming (SQP)	93
A.2 Starting Values for the Optimization	96
A.3 Control Guarantee - Optimization Robustness	96
A.4 Operation in Case of Discontinuous Road Friction Changes	96
A.5 Implementation	97
B Used Parameters	99
B.1 Parameters of the Tire Force Model	99
B.2 PVM	103
B.3 MBVM	103
B.4 Optimization	104
C Table of Names for Electronic Stability Control Systems	105
Bibliography	106