

Dynamic Stability and Control of Tripped and Untripped Vehicle Rollover

Synthesis Lectures on Advances in Automotive Technology

Editor

Amir Khajepour, *University of Waterloo*

The automotive industry has entered a transformational period that will see an unprecedented evolution in the technological capabilities of vehicles. Significant advances in new manufacturing techniques, low-cost sensors, high processing power, and ubiquitous real-time access to information mean that vehicles are rapidly changing and growing in complexity. These new technologies—including the inevitable evolution toward autonomous vehicles—will ultimately deliver substantial benefits to drivers, passengers, and the environment. Synthesis Lectures on Advances in Automotive Technology Series is intended to introduce such new transformational technologies in the automotive industry to its readers.

Dynamic Stability and Control of Tripped and Untripped Vehicle Rollover

Zhilin Jin, Bin Li, and Jingxuan Li

2019

Real-Time Road Profile Identification and Monitoring: Theory and Application

Yechen Qin, Hong Wang, Yanjun Huang, and Xiaolin Tang

2018

Noise and Torsional Vibration Analysis of Hybrid Vehicles

Xiaolin Tang, Yanjun Huang, Hong Wang, and Yechen Qin

2018

Smart Charging and Anti-Idling Systems

Yanjun Huang, Soheil Mohagheghi Fard, Milad Khazraee, Hong Wang, and Amir Khajepour

2018

Design and Advanced Robust Chassis Dynamics Control for X-by-Wire Unmanned Ground Vehicle

Jun Ni, Jibin Hu, and Changle Xiang

2018

Electrification of Heavy-Duty Construction Vehicles

Hong Wang, Yanjun Huang, Amir Khajepour, and Chuan Hu
2017

Vehicle Suspension System Technology and Design

Avesta Goodarzi and Amir Khajepour
2017

© Springer Nature Switzerland AG 2022

Reprint of original edition © Morgan & Claypool 2019

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means—electronic, mechanical, photocopy, recording, or any other except for brief quotations in printed reviews, without the prior permission of the publisher.

Dynamic Stability and Control of Tripped and Untripped Vehicle Rollover

Zhilin Jin, Bin Li, and Jingxuan Li

ISBN: 978-3-031-00372-1 paperback

ISBN: 978-3-031-01500-7 ebook

ISBN: 978-3-031-00005-8 hardcover

DOI 10.1007/978-3-031-01500-7

A Publication in the Springer series

SYNTHESIS LECTURES ON ADVANCES IN AUTOMOTIVE TECHNOLOGY

Lecture #6

Series Editor: Amir Khajepour, *University of Waterloo*

Series ISSN

Print 2576-8107 Electronic 2576-8131

Dynamic Stability and Control of Tripped and Untripped Vehicle Rollover

Zhilin Jin

Nanjing University of Aeronautics & Astronautics

Bin Li

Aptiv PLC

Jingxuan Li

Nanjing University of Aeronautics & Astronautics

SYNTHESIS LECTURES ON ADVANCES IN AUTOMOTIVE TECHNOLOGY
#6

ABSTRACT

Vehicle rollover accidents have been a serious safety problem for the last three decades. Although rollovers are a small percentage of all traffic accidents, they do account for a large proportion of severe and fatal injuries. Specifically, some large passenger vehicles, such as large vans, pickup trucks, and sport utility vehicles, are more prone to rollover accidents with a high center of gravity (CG) and narrow track width. Vehicle rollover accidents may be grouped into two categories: tripped and untripped rollovers. A tripped rollover commonly occurs when a vehicle skids and digs its tires into soft soil or hits a tripping mechanism such as a curb with a sufficiently large lateral velocity. On the other hand, the untripped rollover is induced by extreme maneuvers during critical driving situations, such as excessive speed during cornering, obstacle avoidance, and severe lane change maneuver. In these situations, the forces at the tire-road contact point are large enough to cause the vehicle to roll over. Furthermore, vehicle rollover may occur due to external disturbances such as side-wind and steering excitation. Therefore, it is necessary to investigate the dynamic stability and control of tripped and untripped vehicle rollover so as to avoid vehicle rollover accidents.

In this book, different dynamic models are used to describe the vehicle rollover under both untripped and special tripped situations. From the vehicle dynamics theory, rollover indices are deduced, and the dynamic stabilities of vehicle rollover are analyzed. In addition, some active control strategies are discussed to improve the anti-rollover performance of the vehicle.

KEYWORDS

vehicle rollover, dynamic stability, tripped rollover, rollover index, rollover warning, anti-roll control, active safety of vehicle

Contents

1	Introduction	1
1.1	What Is Vehicle Rollover?	1
1.2	Risk of Vehicle Rollover Accidents	1
1.3	Factors Affecting Vehicle Rollover	1
1.4	Summary	2
2	Dynamic Model of Vehicle Rollover	3
2.1	Roll Plane Model	3
2.2	Yaw-Roll Model	4
2.3	Lateral-Yaw-Roll Model	6
2.4	Yaw-Roll-Vertical Model	9
2.5	Multi-Freedom Model	10
2.6	Multi-Body Dynamic Model	16
2.7	Summary	17
3	Stability of Untripped Vehicle Rollover	21
3.1	Roll Index of Untripped Vehicle Rollover	21
3.1.1	Static Stability Factor	21
3.1.2	Dynamics Stability Factor	22
3.1.3	Lateral Load Transfer Ratio	28
3.2	Rollover Warning	34
3.2.1	Time-to-Rollover	34
3.2.2	Prediction Rollover Warning	36
3.3	Summary	40
4	Stability of Tripped Vehicle Rollover	41
4.1	Roll Index of Tripped Vehicle Rollover	41
4.1.1	Rollover Index on Uneven Roads	41
4.1.2	Rollover Index on Banked Roads	44
4.2	Energy Methods	46
4.3	Summary	48

5	Active Control for Vehicle Rollover Avoidance	49
5.1	Anti-Roll Bar System	49
5.2	Active Suspension System	50
5.3	Active Steering System	51
5.3.1	Active Front Steering Control	52
5.3.2	Pulse Active Rear Steering	52
5.3.3	Four-Wheel Steering	53
5.4	Active Braking System	55
5.5	Integrated Chassis System	58
5.6	Summary	60
6	Rollover Control Strategies and Algorithms	61
6.1	Proportional-Integral-Derivative Control Method	61
6.2	H-infinity Control Method	67
6.3	Model Prediction Control Method	74
6.4	Linear Quadratic Regulator Control Method	83
6.5	Sliding Mode Control Method	86
6.6	Summary	95
7	Conclusions	97
A	Notation	99
	Bibliography	103
	Authors' Biographies	111