

# contents

Used Symbols	<u>xi</u>
Preface	<u>xxi</u>
Foreword I	<u>xxiii</u>
Foreword II	<u>xxv</u>
About the Editor	<u>xxvii</u>

## CHAPTER 1

### Introduction 1

*Prof. Dr. Ludger Frerichs, Prof. Dr.-Ing. Marcus Geimer, and  
Prof. Kalevi Huhtala*

## CHAPTER 2

### Chassis 9

*Prof. Dr. Ludger Frerichs, Prof. Dr.-Ing. Marcus Geimer,  
Markus de la Motte, Fabrizio Panizzolo, and  
Thomas Pippes*

<b>2.1 Construction of Mobile Working Machines (By Ludger Frerichs)</b>	<b><u>9</u></b>
2.1.1 Requirements and Influences	<u>10</u>
2.1.2 Basic Structures and Frame Concepts	<u>13</u>
2.1.3 Design Principles	<u>20</u>
<b>2.2 Axles (By Fabrizio Panizzolo)</b>	<b><u>26</u></b>
2.2.1 Axle Architecture	<u>27</u>
2.2.2 Fundamental Axle Components	<u>32</u>
<b>2.3 Soil-Tire Interaction (By Marcus Geimer)</b>	<b><u>37</u></b>
<b>2.4 Steering Systems (By Markus de la Motte and Thomas Pippes)</b>	<b><u>44</u></b>
2.4.1 Design and Functions of Hydraulically Assisted Steering Systems	<u>45</u>
2.4.2 Design and Functions of Semi-Active and Active Steering Systems	<u>51</u>
<b>References</b>	<b><u>55</u></b>

## CHAPTER 3

Power Train 61

*Sven Bosch, Prof. Danilo Engelmann, Dr.-Ing. Gerhard Geerling, Edwin Heemskerk, Dr.-Ing. Torsten Kohmäscher, Fabrizio Panizzolo, Dr.-Ing. Christian Pohlandt, and Prof. Dr.-Ing. Heinrich Steinhart*

<b>3.1</b>	<b>Primary Energy Provision (By Danilo Engelmann and Christian Pohlandt)</b>	<b><u>62</u></b>
3.1.1	Primary Energy Carriers	<u>62</u>
3.1.2	Characteristics of Prime Movers	<u>64</u>
3.1.3	Combustion Engines	<u>66</u>
3.1.4	Electric Storage	<u>72</u>
<b>3.2</b>	<b>Basics of Power Conversion (By Sven Bosch, Torsten Kohmäscher, Fabrizio Panizzolo, and Heinrich Steinhart)</b>	<b><u>75</u></b>
3.2.1	Mechanic Energy Conversion	<u>76</u>
3.2.2	Hydraulic Energy Conversion	<u>94</u>
3.2.3	Electric Energy Conversion	<u>104</u>
<b>3.3</b>	<b>Traction Drive (By Torsten Kohmäscher and Fabrizio Panizzolo)</b>	<b><u>113</u></b>
3.3.1	Mechanical Gearboxes	<u>113</u>
3.3.2	Hydrodynamic Transmission	<u>118</u>
3.3.3	Hydrostatic Transmission	<u>129</u>
3.3.4	Power-Split Transmission	<u>142</u>
<b>3.4</b>	<b>Function Drives (By Gerhard Geerling and Edwin Heemskerk)</b>	<b><u>160</u></b>
3.4.1	Basic Pilot Actuation (PA) Principles	<u>162</u>
3.4.2	Basic Pump (P) Control Principles	<u>166</u>
3.4.3	Basic Valve Principles	<u>169</u>
3.4.4	Well-Established Systems for Hydraulic Function Drives	<u>177</u>
3.4.5	Comparison between the Systems	<u>202</u>
	<b>References</b>	<b><u>206</u></b>

## CHAPTER 4

Machine Control Concepts 211

*Detlef Hawlitzek*

<b>4.1</b>	<b>Requirements and Trends</b>	<b><u>211</u></b>
4.1.1	Electronics and Hydraulics	<u>212</u>
4.1.2	Safety	<u>212</u>

4.1.3	Driver Assistance Systems	<u>212</u>
4.1.4	Logging of Operational Data	<u>214</u>
4.1.5	Networking	<u>215</u>
<b>4.2</b>	<b>Controller and Sensors</b>	<b><u>215</u></b>
4.2.1	Requirements	<u>215</u>
4.2.2	PWM and Dither	<u>218</u>
<b>4.3</b>	<b>Automation Technologies</b>	<b><u>222</u></b>
4.3.1	Machines with a Central Controller	<u>222</u>
4.3.2	Machines with Decentralized Control Technology/ Distributed Intelligence	<u>223</u>
<b>4.4</b>	<b>Communication and Networking</b>	<b><u>225</u></b>
4.4.1	Bus Systems in Mobile Working Machinery	<u>225</u>
4.4.2	Telemetry and Remote Service	<u>236</u>
<b>4.5</b>	<b>Functional Safety Aspects in Mobile Working Machines</b>	<b><u>244</u></b>
4.5.1	The Standards	<u>246</u>
4.5.2	Safety Integrity	<u>248</u>
4.5.3	Right Assessment and Consistent Implementation	<u>248</u>
	<b>References</b>	<b><u>254</u></b>

## CHAPTER 5

# Innovative Drive Concepts 257

*Prof. Dr. Naseem Daher, Prof. Dr.-Ing. Marcus Geimer,  
and Roman Iwantysyn*

<b>5.1</b>	<b>Innovative Hybrid Drive Systems</b>	<b><u>260</u></b>
5.1.1	Introduction	<u>261</u>
5.1.2	Series-Parallel Hybrid Displacement Controlled Systems	<u>264</u>
5.1.3	Coupled Displacement Controlled Actuation	<u>267</u>
5.1.4	A Blended Hydraulic Hybrid System for On-Road Vehicles	<u>272</u>
<b>5.2</b>	<b>Innovative Displacement Controlled Linear Drive Systems</b>	<b><u>275</u></b>
5.2.1	Introduction	<u>275</u>
5.2.2	Closed Circuit Linear Drive Example	<u>282</u>
5.2.3	Open Circuit PCA Example	<u>285</u>
5.2.4	Electro-Hydraulic Actuation (EHA)	<u>289</u>
5.2.5	Challenges for the Introduction of DC Actuation	<u>290</u>

<b>5.3</b>	<b>Further Innovative DC Machine Concepts</b>	<b><u>294</u></b>
5.3.1	Closed Circuit Flow Sharing Concept	<u>294</u>
5.3.2	DC Steer-By-Wire Technology	<u>295</u>
5.3.3	Active Vibration Damping Using Swashplate Control	<u>299</u>
5.3.4	Pump Vibration Damping Using Swashplate Control	<u>302</u>
5.3.5	Secondary Control and Hydraulic Transformers	<u>305</u>
<b>5.4</b>	<b>Further Innovative Systems</b>	<b><u>309</u></b>
5.4.1	Digital Hydraulics	<u>309</u>
5.4.2	Independent Metering	<u>313</u>
5.4.3	Sustainable Energy Sources	<u>314</u>
	<b>References</b>	<b><u>316</u></b>

## CHAPTER 6

# Selected Machine Examples 323

*Dr.-Ing. Rainer Bavendiek, Dr. Martin Kremmer, and  
Dr.-Ing. Herbert Pfab*

<b>6.1</b>	<b>Tractor (By Martin Kremmer)</b>	<b><u>323</u></b>
6.1.1	Introduction	<u>323</u>
6.1.2	Concept and Configurations	<u>333</u>
6.1.3	Interfaces for Applications	<u>340</u>
6.1.4	Tractor Applications	<u>351</u>
<b>6.2</b>	<b>Wheel Loader (By Herbert Pfab)</b>	<b><u>356</u></b>
6.2.1	Application	<u>358</u>
6.2.2	Machine Concepts	<u>360</u>
6.2.3	Process Connection	<u>365</u>
6.2.4	Traction Drive	<u>372</u>
6.2.5	Drivers Cab	<u>380</u>
<b>6.3</b>	<b>Forklift Truck (By Rainer Bavendiek)</b>	<b><u>383</u></b>
6.3.1	Classification and Standards	<u>384</u>
6.3.2	Requirements and Main Functions	<u>386</u>
6.3.3	Frame and Counterbalance	<u>393</u>
6.3.4	Powertrain	<u>395</u>
6.3.5	Hydraulics	<u>399</u>
6.3.6	Operator Working Place	<u>402</u>
6.3.7	Electric Controls and Software	<u>407</u>
6.3.8	Mast and Attachments	<u>410</u>
6.3.9	Trends and Future Developments	<u>411</u>
	<b>References</b>	<b><u>413</u></b>

**CHAPTER 7****Summary** 421*Prof. Dr.-Ing. Marcus Geimer*About the Authors 425Mobile Working Machines 431Index 433