

Manfred Harrer · Peter Pfeffer *Editors*

Steering Handbook

 Springer

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Preface

In recent years, steering system technologies have undergone rapid development. This was caused by increased regulatory requirements in the areas of environment and safety, through the increased comfort requirements of the customer and not least by the continuing cost pressure. New ways have been taken up for steering components such as steering wheel, steering column, and steering gear. The most substantial change has been the progressive substitution of conventional hydraulic steering systems with electrical steering systems. With this change in technology a variety of new steering functions have been made possible. It is therefore not surprising that the steering system development as such occupies an ever-increasing role in modern chassis development. Due to the lack of a standard English book on the subject of steering systems/steering behavior, which describes the current state of the art, we decided with Springer Verlag to publish the German Steering Handbook also in English. We have taken into account the different interests and requirements of automotive manufacturers, suppliers, and universities in such a standard work by the involvement of proven experts from these areas.

In the first part of this book, the kinematic and vehicle dynamics of steering is explained and discussed, and also the influence of the suspension characteristics for the steering operation is investigated. A chapter is devoted to the interaction between driver and vehicle to analyze the aspects of steering feel. The central chapters of this book are devoted to individual steering modules, their design, and component tests. Described in detail are the components steering wheel, steering column with intermediate steering shaft, and the steering rack in mechanical, hydraulic, and electro-mechanical design. Special steering system technologies such as the superimposed steering system and four-wheel steering are also discussed in detail. Much attention was paid to illustrate the current state of the steering system technology and its interaction with the entire vehicle comprehensibly. Also important secondary aspects such as acoustic performance, energy requirements, and functional safety are treated in detail. Furthermore, the possibilities regarding driver assistance functions enabled by modern steering systems are shown. The profound expertise of nearly 40 experts from industry and academia

was utilized for the creation of the steering handbook. We would like to thank all the authors for their expertise and perseverance. Also we thank Springer for publishing. Only through the dedication of all those involved, this textbook has been possible.

The readers of this book were asked by us to give feedback for improvements. Please send your suggestions to the following email address: peter.pfeffer@hm.edu. We will accommodate your suggestions in the next editions.

Stuttgart, Feldafing
January 2014

Manfred Harrer
Peter Pfeffer

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Abbreviations and Symbols

Abbreviations

4WAS	4 Wheel Active Steer (Nissan)
ABS	Anti-Lock Brake System
AC	Alternating Current
AD	Analog-Digital Converter
AFS	Active Front Steering
AHK	Aktive rear axle kinematic
AMR	Anisotropen Magnetoresistiv
APA	Paraxial drive unit
ASIC	Application-Specific Integrated Circuit
ASIL	Automotive Safety Integrity Level
ASM	Asynchronous Motor
ASM	Assembly
ATF	Automatic Transmission Fluid
BCM	Body-Control-Modul
BLDC	Brushless Direct Current Motor
BRIC	Brasil, Russia, India, China
CAE	Computer Aided Engineering
CAN	Controller Area Network
C-EPS	Steering Column Assisted EPS
CFD	Computational Fluid Dynamics
CFK	Fiber-Reinforced Plastic Material
CGR	Constant Gear Ratio
CPU	Central Processor Unit
CR	Chloroprene Rubber
CR-EPS	Rack Concentric EPS
CS	Circular-Spline
CSM	Chlorosulphonated-Polyethylene-Rubber
CV	Concept Verification
DBC	Direkt Bonded Copper

DBV	Pressure Limitation Valve
DC	Direct Current
DCM	Direct Current Motor
DMS	Strain gauge
DP-EPS	Dual Pinion EPS
DV	Design Verification
EC	Electronically Commutated Motor
ECE	Economic Commission for Europe
ECU	Electronic Control Unit
EHPS	Electro Hydraulic Power Steering
EMC	Electro Magnetic Compatibility
EPS	Electric Power Steering
EPSapa	EPS with Paraxial Drive
EPSc	Column EPS
EPSdp	Dual Pinion EPS
EPSp	Pinion EPS
EPSrc	Rack Concentric EPS
ESD	Electrostatic Discharge
ESP	Elektronisches Stability Program
ESV	Experimental-Safety-Vehicle
EU	European Union
EV	Electric Vehicle
EVLS	Elektric adjustable steering column
EWG	European Economic Community (Europäische Wirtschaftsgemeinschaft)
FA	Front Axle
FAD	Front Axle Damper
FB	Flex-Bearing
FCV	Fuel Cell Vehicle
FEA/FEM	Finite-Element-Analysis/Method
FMVSS	Federal Motor Vehicle Safety Standard
FS	Flex-Spline
FS (FDR)	Vehicle Stability (Vehicle Dynamics Control)
FS (VS)	Vehicle Stability (Feedforward)
GAAI	German Association of the Automotive Industry
GFK	Glass fiber reinforced plastic
GIS	German Institute for Standardization
GND	Ground
HA	Rear Axle
HAD	Rear Axle Damper
HEV	Hybrid Electric Vehicle
HICAS	High Capacity Actively Controlled Suspension
HNBR	Hydrierter Acrylnitrilbutadien-Kautschuk
HPS	Hydraulic Power Steering
IAS	Integral Aktiv Steering

IC	Electrical Circuit
IEC	International Electrotechnical Commission
IGBT	Insulated-Gate Bipolar Transistor
IMS	Insulated Metal Substrate
ISO	International Standards Organization
KGT	Recirculating ball
KTL	Cathodic dip painting
LCV	Light Commercial Vehicle
LDM	Free steering torque
LDS	Steering nibble (steering torsional vibrations)
LDW	Lane Departure Prevention
LED	Light Emitting Diode
LIN	Local Interconnected Network
LKS	Lane Keeping Support
MAC	Manual Adjustable column
MFS	Magnetic Field Sensor
MFS	Multi-Function Switch
ML	Engine Mount
MOST	Media Oriented Systems Transport
MPA	Motor-Pump-Unit
MR	Magneto-resistiv
MS	Manual Steering
NBR	Nitrile Butadiene Rubber
NEDC	New European Driving Cycle
Nfz CV	Commercial Vehicle
NHTSA	National Highway Safety Traffic Administration
NVH	Noise Vibration Harshness
OA-EPS	Offset Axis-EPS
OEM	Original Equipment Manufacturer
OOP	Out Of Position
OSEK/VDX	Offene Systeme und deren Schnittstellen für die Elektronik in Kraftfahrzeugen/Vehicle Distributed eExecutive
PA	Polyamide
PC	Passenger Car
PCB	Printed Circuit Board
PDC	Park Distance Control
PEEK	Polyetherketone
P-EPS	Pinion EPS
P-EPS	Paraxial EPS
PMSM	Permanent Magnet Synchronous Motor
POM	Polyoxymethylene
ppm	parts per million
PTFE	Polytetrafluoroethylene
PUR	Polyurethane
PV	Product Validation

PVD	Physical Vapour Deposition
PWM	Pulse Width Modulation
QM	Quality Management
RAM	Random Access Memory
ROM	Read Only Memory
ROW	Rest of the World
RTLG	Road Traffic Licensing regulations
SA	Steering Arm
SAE	Society of Automotive Engineers
SAW	Surface Acoustic Wave
SCU	Steering Control Unit
SH	Sensor Host
SIL	Safety Integrity Level
SISO	Single Input Single Output
SMD	Surface Mounted Device
SR	Switched Reluctance
SUV	Sport Utility Vehicle
TCR	Turning Circle Reduction
TFC	Thick Film Copper
THC	Through Hole Component
UV	Ultra Violette
VCC	Common-Collector Voltage
VGR, VGS	Variable Gear Ratio
WG	Wave Generator
ZFLS	ZF Lenksysteme GmbH (now Robert Bosch Automotive Steering GmbH)

Formula Index

α	Tire side slip angle (rad)
α	Working angle of joint steering countershaft (rad)
β	Slip angle (rad)
β	Angle between joint planes (rad)
$\beta T/\beta U$	Transmission angle
βx	Separation ratio
βz	Helix angle (rad)
γ	Shearing angle (rad)
γ	Offset angle steering countershaft (rad)
γ	Installation angle bevel axle (rad)
$\delta *$	Steering arm rotation angle (rad)
δ, δ	Steering angle, velocity (rad, rad/s)
δA	Ackermann angle (rad)
δD	Dynamic reference steering angle (rad)
δG	Rotation angle of steering arm lever (rad)

δh	Rear steering angle (rad)
δH	Steering wheel angle (rad)
δH^*	Bevel rotation axle (rad)
δLS	Steering column angle (rad)
δM	Superposing angle (rad)
$\delta o, \max$	Maximum steering angle of front outer wheel (rad)
δv	Front steering angle (rad)
$\Delta\delta$	Required difference steering angle (rad)
$\Delta\delta A$	Track difference angle, difference steering angle according to Ackermann (rad)
$\Delta\delta F$	Difference steering angle (rad)
$\Delta\delta H$	Steering wheel angle (rad)
$\Delta\delta H_e$	Steering system compliance at steering wheel (rad)
$\Delta\delta H_{Re}$	Steering wheel rest angle (rad)
ε	Wheel camber angle (rad)
$\varepsilon V, \phi, F$	Roll induced steering factor (rad)
$\varepsilon \alpha$	Gearing transverse contact ratio
$\varepsilon \beta$	Gearing overlap ratio
$\varepsilon \gamma$	Gearing overall overlap
$\Delta\varepsilon V, \phi, F$	Camber part due to rolling (rad)
ζ	Attenuation ratio
η	Efficiency
η	Frequency rate
k	Is Curvature (1/m)
λ	Direction of steering arm (rad)
ρ	Path curve radius (m)
σ	Spread (rad)
τ	Castor angle (rad)
ϕ	Rotation angle (rad)
χ	Roll angle (1/m)
Ψ, ψ	Yaw angle, yaw angle velocity (rad), (rad/s)
ω	Angle velocity (rad/s)
ωE	Cutt-off frequency (rad/s)
ωn	Steering system natural frequency (1/s)

Symbol Description

a	Air
dyn	Dynamic
o (curve)	Outside
i (curve)	Inside
F	Front
R	Rear

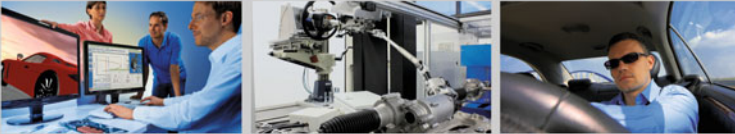
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