

Automotive Transmissions

Second Edition

Harald Naunheimer · Bernd Bertsche ·
Joachim Ryborz · Wolfgang Novak

Automotive Transmissions

Fundamentals, Selection, Design
and Application

In Collaboration with Peter Fietkau

Second Edition

With 487 Figures and 85 Tables

 Springer

Dr.-Ing. Harald Naunheimer
Vice President Corporate Research
and Development
ZF Friedrichshafen AG
Graf-von-Soden-Platz 1
88046 Friedrichshafen
Germany
harald.naunheimer@zf.com

Professor Dr.-Ing. Bernd Bertsche
Director
Universität Stuttgart
Institute of Machine Components
Pfaffenwaldring 9
70569 Stuttgart
Germany
bernd.bertsche@ima.uni-stuttgart.de

Dr.-Ing. Joachim Ryborz
Project Manager
Development Transmission
for Light Commercial Vehicle
ZF Friedrichshafen AG
Alfred-Colsman-Platz 1
88045 Friedrichshafen
Germany
joachim.ryborz@zf.com

Dr.-Ing. Wolfgang Novak
Development Engineer
Daimler AG
Mercedesstraße 119
70546 Stuttgart
Germany
wolfgang.novak@daimler.com

In Collaboration with
Dipl.-Ing. Peter Fietkau
Scientific Employee
Universität Stuttgart
Institute of Machine Components
Pfaffenwaldring 9
70569 Stuttgart
Germany
peter.fietkau@ima.uni-stuttgart.de

Translator
Aaron Kuchle
Foreign Language Institute
Yeungnam University
214-1 Dae-dong
Gyeongsan, Gyeongbuk
Korea 712-749
aaronkuchle@yahoo.com

ISBN 978-3-642-16213-8 e-ISBN 978-3-642-16214-5
DOI 10.1007/978-3-642-16214-5
Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2010937846

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Cover design: eStudio Calamar S.L.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface to the Second Revised and Expanded Edition

“Automotive Transmissions” was first published in Germany in May 1994. It was so well received that we decided to publish the book in English in 1999. Since then much has happened in the automotive and transmission sectors.

Imperatives imposed upon the development of automotive transmissions are improving driving performance, increasing driving comfort and ease of use, increasing reliability and service life, reducing weight and installation space, raising efficiency levels, profiling the brand image, reducing costs and, above all, reducing fuel consumption and pollutant emissions. Markets and market mechanisms for passenger cars and commercial vehicles differ and the emphasis placed on these requirements differs in turn. Common to all cases is that a variety of requirements leads by necessity to a conflict of goals. Approaches that can help to solve the goal conflicts are individual usage-optimised transmission solutions, higher integration of submodules, introducing more functionality and generating superordinate functions by means of networking with other vehicle components.

In the case of passenger cars, the trend toward individualised designs has caused strong segmentation with numerous vehicle classes. This has also led to a massive diversification among transmission designs, with individual solutions and competing concepts: manual transmissions (MT), automated manual transmissions (AMT), dual clutch transmissions (DCT), conventional automatic transmissions (AT), continuously variable transmissions (CVT) and hybrid drives. The “black and white”, manual vs. automatic situation existing back in 1990 no longer applies. In the case of commercial vehicle transmissions, the mechanical geared transmission with 6 to 16 speeds of either single-range or multi-range design are standard. In the heavy-duty truck segment, AMT have become successful in Europe. Their path led from semi-automatic designs right up to fully automated transmissions. Increasing integration of peripheral parts and submodules into the transmission has led to lighter, more compact and more reliable aggregates.

Electrics and electronics, actuator technology and sensor technology have played a defining role in many innovations in the area of automotive transmissions. Software is responsible for many of the functions of transmission systems, and thus for much of their customer benefit. The increase in function content and networking with other components of the vehicle leads to changes in the chain of responsibility between vehicle and transmission manufacturers.

The correct evaluation of trends in the market, in engineering and technology has taken on greater importance. The tasks now are to recognize and evaluate future demands early on, to derive new strategies and products from this basis and to develop and finally to produce these products for the market cost-effectively while maintaining a high level of quality. The goal of this book is to provide some of the tools required to do this. It intends to show the process of product development for automotive transmissions in its entirety.

The second edition integrates innovations in automotive transmissions into the systematic framework established in the first edition. Approximately 40% of the content of the second edition is either entirely new or revised with new data. As with the first edition, however, the goal is not to introduce the most current developments or to be exhaustive in details, but to provide the reader with lines of reasoning and to demonstrate approaches. Theoretical principles and concepts are explained that are of general validity and hence of enduring relevance. Therefore beside current designs, transmission systems that are no longer in production are also presented.

In order to strengthen the relation to praxis, the second edition has consolidated the knowledge of experts from different sub-disciplines. Our thanks go to them: *history*: Hans-Jörg Dach (ZF); *passenger car MT/AMT*: Christian Hoffmann (Getrag); *passenger car DCT*: Michael Schäfer (VW), Michael Kislak (VW), Michael Ebenhoch (ZF); *passenger car AT*: Christoph Dörr (Mercedes-Benz); *passenger car/commercial vehicle hybrid*: Stefan Kilian (ZF); *passenger car CVT*: Peter Schiberna (Audi); *commercial vehicle AMT*: Carsten Gitt (Mercedes-Benz); *commercial vehicle CVT*: Karl Grad (ZF); *gearing*: Franz Joachim (ZF); *operational fatigue strength*: Karl-Heinz Hirschmann (Uni Rostock); *acoustics*: Martin Hildebrand (Ford); *external gearshift system*: Andreas Giefer (ZF); *multi-plate clutches*: Dietmar Frey (ZF); *dry clutches*: Benedikt Schauder (ZF Sachs); *wet dual clutches*: Johannes Heinrich (BorgWarner); *bearings*: Oskar Zwirlein (FAG); *seals*: Werner Haas (Uni Stuttgart); *retarders*: Reinhold Pittius (Voith); *all-wheel drive*: Dieter Schmidl (Magna Powertrain), Andreas Allgöwer (Getrag), Hubert Gröhlich (VW); *electronic transmission control*: Josef Schwarz (ZF); *calculation tools*: Marco Plieske (ZF); *driving simulation*: Friedemann Jauch (ZF); *manufacturing*: Christian Wagner (ZF); *testing*: Peter Brodbeck (Porsche) – and many others who supported us with their advice and expertise.

We would like to thank the following companies for up-to-date and realistic illustrations: Allison, Audi, BMW, BorgWarner, Eaton, Ford, Getrag, Honda, LuK, Magna Powertrain, Mercedes-Benz, Opel, Porsche, Toyota, Voith and VW. Special thanks are due to ZF for all their support during the development of this book.

This English language edition could not have come to fruition without the assistance of many contributors. We are particularly indebted to Dipl.-Ing. Peter Fietkau as the manager and co-ordinator of the project, and to his assistants at the Institute of Machine Components (IMA), University of Stuttgart. We thank Springer-Verlag for their good cooperation. Our special thanks go to our families for their great patience, understanding and support during the three years spent preparing this book.

In 2002, Professor Dr.-Ing. Gisbert Lechner passed away. He was the initiator and author of the first English edition of “Automotive Transmissions”. We see the second edition as a continuation of his excellent work.

Preface

It was in 1953 that H. Reichenbächer wrote the first book on motor vehicle transmission engineering. At that time, the German motor industry produced 490 581 vehicles including cars, vans, trucks, busses and tractor-trailer units. In 1992, production had reached 5.2 million. The technology at that time only required coverage of certain aspects, and Mr Reichenbächer's book accordingly restricted itself to basic types of gearbox, gear step selection, gear sets with fixed axles, epicyclic systems, Föttinger clutches and hydrodynamic transmissions.

Automotive engineering and the technology of mechanism design have always been subject to evolution. The current state of the art is characterised by the following interrelations:

Environment - Traffic - Vehicle - Transmission.

Questions such as economy, environment and ease of use are paramount. The utility of a transmission is characterised by its impact on the traction available, on fuel consumption and reliability, service life, noise levels and the user-friendliness of the vehicle.

There are new techniques which now have to be taken into account, relating to development methodology, materials technology and notably strength calculation. Examples include operational fatigue strength calculations, the introduction of specific flank corrections, taking account of housing deformation, and the need for light-weight construction.

Transmission design engineering has been enriched by numerous variants. The manual two-stage countershaft transmission, preferred for longitudinal engines, and the single-stage countershaft transmission preferred for transverse engines now have many sub-variants, e.g. automatic transmissions, continuously variable transmissions, torque converter clutch transmissions, dual clutch transmissions, and transmissions for all-wheel drive.

The engine and transmission must increasingly be considered as one functional unit. The terms used are "powertrain matching" and "engine/transmission management". This can only be achieved by an integrated electronic management system covering the mechanical components in both engine and transmission.

The technique of systematic design developed in the 1960s, and the increasing use of computers for design, simulation and engineering (CAD) are resulting in ever-reducing development cycles. This trend is reinforced by competitive pressures. Systematic product planning is another significant factor in this regard.

It was therefore necessary to create an entirely new structure for the present book "Automotive Transmissions". Modern developments have to be taken into account. The great diversity and range of issues in developing transmissions made it difficult to select the material for this completely new version of "Automotive Transmissions", especially within the prevailing constraints. Not every topic could

be covered in detail. In those places where there is an established literature, the authors have chosen to rely on it in the interests of brevity.

The purpose of this book is to describe the development of motor vehicle transmissions as an ongoing part of the vehicle development system. Only by actively taking this interaction into account is it possible to arrive at a fully viable transmission design. The aim is to highlight the basic interrelations between the drive unit, the vehicle and the transmission on the one hand, and their functional features such as appropriate gear selection, correct gear step, traction diagram, fuel consumption, service life and reliability on the other. Of course, another major concern was to represent the various engineering designs of modern vehicle transmissions in suitable design drawings.

The book is addressed to all engineers and students of automotive engineering, but especially to practitioners and senior engineers working in the field of transmission development. It is intended as a reference work for all information of importance to transmission development, and is also intended as a guide to further literature in the field.

Without the assistance of numerous people this book would not have been written. We would like to thank Dr Heidrun Schröpel, Mr Wolfgang Elser, Dr Ekkehard Krieg, Dr Winfried Richter, Mr Thomas Spörl, Mr Thilo Wagner, Dr Georg Weidner and Professor Lothar Winkler for researching and revising chapters. We also wish to acknowledge the contribution of numerous assistants and postgraduates for important work on specific aspects.

We wish to thank Christine Häbich for her professional editing. We would like to thank many employees and scientific assistants of the IMA (Institute of Machine Components) for reviewing and checking various parts of the text.

Such a book cannot be published without current practical illustrations. The publishers wish to acknowledge their gratitude to numerous companies for making illustrations available: Audi AG, BMW AG, Eaton GmbH, Fichtel & Sachs AG, Ford Werke AG, GETRAG, Mercedes-Benz AG, Adam Opel AG, Dr.-Ing. h.c. Porsche AG, and Volkswagen AG. We are particularly indebted to ZF Friedrichshafen AG who have always been most forthcoming in responding to our numerous requests for graphic material.

We are also indebted to Springer-Verlag for publishing this book. We would particularly like to thank Mr M Hofmann, whose faith in our project never wavered, and whose gentle but firm persistence ensured that the book did indeed reach completion. Dr Merkle then prepared the work for printing. We must also thank the publisher of the "Design Engineering Books" series, Professor Gerhard Pahl for his patience and advice. Our thanks especially to our families for their understanding and support.

Stuttgart,
May 1994

Gisbert Lechner
Harald Naunheimer

Contents

Terms and Symbols	XVII
1 Introduction	1
1.1 Preface	1
1.2 History of Automotive Transmissions	7
1.2.1 Basic Innovations	7
1.2.2 Development of Vehicles and Drive Units.....	9
1.2.3 Stages in the Development of Automotive Transmissions.....	10
1.2.4 Development of Gear-Tooth Systems and other Transmission Components	20
1.2.5 Development of Torque Converters and Clutches.....	23
1.2.6 Investigation of Phenomena: Transmission Losses and Efficiency	24
1.2.7 Historical Overview	26
2 Overview of the Traffic – Vehicle – Transmission System.....	28
2.1 Fundamental Principles of Traffic and Vehicle Engineering.....	28
2.1.1 The Significance of Motor Vehicles in our Mobile World.....	30
2.1.2 Trends in Traffic Engineering	34
2.1.3 Passenger and Goods Transport Systems	36
2.1.4 Alternative Transport Concepts.....	40
2.2 The Market and Development Situation for Vehicles, Gearboxes and Components	41
2.2.1 Market Situation and Production Figures.....	41
2.2.2 Development Situation	46
2.3 Basic Elements of Vehicle and Transmission Engineering	46
2.3.1 Systematic Classification of Vehicles and Vehicle Use	47
2.3.2 Why do Vehicles Need Gearboxes?	49
2.3.3 Main and Auxiliary Functions of Vehicle Transmissions, Requirements Profile.....	51
2.3.4 Interrelations: Direction of Rotation, Transmission Ratio, Torque	52
2.3.5 Road Profiles, Load Profiles, Typical Vehicle Use and Driver Types.....	56
2.4 Fundamental Performance Features of Vehicle Transmissions	58
2.4.1 Service Life and Reliability of Transmissions	58
2.4.2 Centre Distance Characteristic Value.....	60

2.4.3	Gearbox Mass Characteristic Value	62
2.4.4	Gearbox Cost Characteristic Value	64
2.4.5	Gearbox Noise	65
2.4.6	Gearbox Losses and Efficiency	66
2.5	Trends in Transmission Design	67
3	Mediating the Power Flow	73
3.1	Power Requirement	73
3.1.1	Wheel Resistance	73
3.1.2	Adhesion, Dynamic Wheel Radius and Slip	75
3.1.3	Air Resistance	77
3.1.4	Gradient Resistance	79
3.1.5	Acceleration Resistance	80
3.1.6	Total Driving Resistance	81
3.1.7	Efficiency Map	82
3.2	Diversity of Prime Movers	85
3.2.1	Overview	86
3.2.2	Electric Drive with Electric Energy Accumulator	87
3.2.3	Electric Drive with Fuel Cell	87
3.2.4	Hybrid Drive	89
3.3	Power Output, Combustion Engine Characteristic	93
3.3.1	Torque/Engine Speed Characteristic	95
3.3.2	Engine Spread, Throttle Map	97
3.3.3	Consumption Map	98
4	Power Conversion: Selecting the Ratios	100
4.1	Powertrain	101
4.2	Total Ratio and Overall Gear Ratio	102
4.2.1	Overall Gear Ratio $i_{G,tot}$	103
4.2.2	Selecting the Largest Powertrain Ratio $i_{A,max}$	104
4.2.3	Selecting the Smallest Powertrain Ratio $i_{A,min}$	105
4.2.4	Final Ratio	109
4.3	Selecting the Intermediate Gears	109
4.3.1	Velocity/Engine-Speed Diagram	110
4.3.2	Geometrical Gear Steps	111
4.3.3	Progressive Gear Steps	111
4.4	Ratio Variation in Continuously Variable Transmissions	113
5	Matching Engine and Transmission	115
5.1	Traction Diagram	117
5.1.1	Deriving a Traction Diagram (Example)	119
5.1.2	Engine Braking Force	120
5.1.3	Geared Transmission with Dry Clutch	123
5.1.4	Geared Transmission with Torque Converter	123
5.2	Vehicle Performance	126
5.2.1	Maximum Speed	126

5.2.2	Climbing Performance	127
5.2.3	Acceleration Performance	128
5.3	Fuel Consumption.....	128
5.3.1	Calculating Fuel Consumption (Example).....	129
5.3.2	Determining Fuel Consumption by Measurement.....	131
5.3.3	Reducing Fuel Consumption	133
5.3.4	Continuously Variable Transmissions.....	134
5.4	Emissions.....	134
5.5	Dynamic Behaviour of the Powertrain, Comfort.....	138
6	Vehicle Transmission Systems: Basic Design Principles	140
6.1	Arrangement of the Transmission in the Vehicle	140
6.1.1	Passenger Cars	140
6.1.2	Commercial Vehicles	143
6.1.3	All-Wheel Drive Passenger Cars.....	146
6.1.4	Transverse and Longitudinal Dynamics with All-Wheel Drive.....	150
6.2	Transmission Formats and Designs	151
6.2.1	Transmission Format.....	152
6.2.2	Transmission Design	153
6.3	Basic Gearbox Concept	154
6.3.1	Shifting with Power Interruption.....	155
6.3.2	Shifting without Power Interruption.....	156
6.3.3	Continuously Variable Transmissions without Power Interruption.....	157
6.4	Gear Sets with Fixed Axles, Countershaft Transmissions and Epicyclic Gears.....	158
6.5	Solution Principles for Part Functions, Evaluation.....	160
6.5.1	Reverse Gear as Example.....	161
6.6	Passenger Car Transmissions.....	163
6.6.1	Manual Passenger Car Transmissions (MT)	164
6.6.2	Automated Manual Passenger Car Transmissions (AMT).....	169
6.6.3	Dual Clutch Passenger Car Transmissions (DCT)	172
6.6.4	Automatic Passenger Car Transmissions (AT)	174
6.6.5	Passenger Car Hybrid Drives	182
6.6.6	Continuously Variable Passenger Car Transmissions (CVT)..	186
6.7	Commercial Vehicle Transmissions	189
6.7.1	Manual Commercial Vehicle Transmissions (MT).....	192
6.7.2	Automated Manual Commercial Vehicle Transmissions (AMT).....	207
6.7.3	Commercial Vehicle Torque Converter Clutch Transmissions (TCCT).....	213
6.7.4	Automatic Commercial Vehicle Transmissions (AT).....	215
6.7.5	Commercial Vehicle Hybrid Drives.....	216
6.7.6	Continuously Variable Commercial Vehicle Transmissions (CVT).....	219

6.8	Final Drives	222
6.8.1	Axle Drives for Passenger Cars	223
6.8.2	Axle Drives for Commercial Vehicles	225
6.8.3	Differential Gears and Locking Differentials	227
6.8.4	Hub Drives for Commercial Vehicles	232
6.8.5	Transfer Gearboxes	233
6.9	Power Take-Offs	234
7	Design of Gearwheel Transmissions for Vehicles	237
7.1	Gearwheel Performance Limits	237
7.1.1	Causes and Types of Damage	239
7.1.2	Calculating the Tooth Root Load Capacity	243
7.1.3	Calculating the Pitting Load Capacity	245
7.1.4	Calculating the Scuffing Load Capacity	246
7.2	Estimating Centre Distance	247
7.3	Estimating Face Widths	249
7.4	Operational Fatigue Strength and Service Life	250
7.4.1	The Wöhler Curve	252
7.4.2	Load Profile and Counting Procedure	254
7.4.3	Damage Accumulation Hypothesis	257
7.5	Developing Low-Noise Transmissions	264
7.5.1	Transmission Noise and Its Causes	265
7.5.2	How Noise Reaches the Ear	269
7.5.3	Assessment Criteria	270
7.5.4	Countermeasures	274
8	Specification and Design of Shafts	278
8.1	Typical Requirements in Vehicle Transmissions	278
8.1.1	Configuration of Shafts in Vehicle Transmissions	278
8.1.2	Designing for Stress and Strength	279
8.1.3	Deflection	280
8.1.4	Vibration Problems	280
8.2	General Design Guidelines	281
8.3	Transmission Drive Shaft Strength Design	283
8.3.1	Loading	283
8.3.2	Bearing Reactions	286
8.3.3	Spatial Beam Deflection	286
8.3.4	Shear Force and Bending Moment Diagrams	287
8.3.5	Critical Cross-Section	289
8.3.6	Stresses	290
8.3.7	Preliminary Specification of the Shaft Diameter	293
8.3.8	Designing for Endurance Strength	294
8.3.9	Designing for Operational Fatigue Strength	294
8.3.10	Common Shaft Materials	296
8.4	Calculating Deformation	296
8.5	Flow Chart for Designing Transmission Shafts	297

9	Gearshifting Mechanisms	300
9.1	Systematic Classification of Shifting Elements	302
9.1.1	Shifting Elements for Transmissions with Power Interruption.....	303
9.1.2	Shifting Elements for Transmissions without Power Interruption.....	306
9.1.3	Shift-by-Wire	309
9.2	Layout and Design of Synchronizers.....	310
9.2.1	Synchronizer Functional Requirements	310
9.2.2	The Synchronizing Process	316
9.2.3	Design of Synchronizers	321
9.2.4	The Tribological System of Synchronizers	334
9.2.5	Engineering Designs	336
9.2.6	Alternative Transmission Synchronizers.....	342
9.2.7	Detail Questions	343
9.3	Layout and Design of Multi-Plate Clutches.....	344
9.3.1	Multi-Plate Clutch Requirements	346
9.3.2	The Shifting Process.....	346
9.3.3	Design of Multi-Plate Clutches	350
9.3.4	Tribological System of Multi-Plate Clutches	355
9.3.5	Engineering Designs	358
9.3.6	Detail Questions	363
9.4	Parking Locks.....	365
9.4.1	Mechanically Activated Parking Locks.....	366
9.4.2	Electrically Activated Parking Locks.....	368
9.4.3	Detail questions.....	369
10	Moving-Off Elements	371
10.1	Dry Clutches.....	374
10.1.1	Structure of Dry Clutches.....	374
10.1.2	Design of Dry Clutches	385
10.1.3	Dry Multi-Plate Clutches.....	387
10.2	Wet Clutches.....	388
10.3	Dual Clutches	390
10.4	Hydrodynamic Clutches and Torque Converters.....	393
10.4.1	Principles.....	394
10.4.2	Hydrodynamic Clutches and their Characteristic Curves.....	397
10.4.3	Torque Converters and their Characteristic Curves.....	399
10.4.4	Engine and Torque Converter Working Together	401
10.4.5	Practical Design of Torque Converters	406
10.4.6	Engineering Designs	406
10.4.7	Design Principles for Increasing Efficiency.....	410
11	Design and Configuration of Further Design Elements	420
11.1	Bearings.....	420
11.1.1	Selecting Rolling Bearings.....	421

11.1.2	Rolling Bearing Design.....	423
11.1.3	Design of Rolling Bearings.....	426
11.1.4	Plain Bearings – Bearing Bushes and Thrust Washers.....	428
11.2	Lubrication of Gearboxes, Gearbox Lubricants	431
11.2.1	Bearing Lubrication	432
11.2.2	Principles of Lubricating Gearwheel Mechanisms.....	432
11.2.3	Selecting the Lubricant	435
11.2.4	Selecting Lubricant Characteristics.....	436
11.2.5	Lifetime Lubrication in Vehicle Gearboxes.....	440
11.2.6	Testing the Scuffing Resistance of Gearbox Lubricants	440
11.3	Oil Supply and Oil Pumps	442
11.3.1	Oil Supply	442
11.3.2	Oil Pumps.....	445
11.3.3	Detail Questions.....	451
11.4	Gearbox Housing.....	453
11.4.1	Gearbox Housing Design	453
11.4.2	Venting Gearboxes.....	456
11.5	Gearbox Sealing	460
11.5.1	Seals for Static Components	460
11.5.2	Seals for Rotating Components.....	464
11.5.3	Seals for Reciprocating Round Components.....	466
11.5.4	Practical Examples.....	467
11.5.5	Final Inspection for Detecting Leakage	468
11.6	Vehicle Continuous Service Brakes	469
11.6.1	Definitions.....	470
11.6.2	Engine Braking Systems	471
11.6.3	Retarders	472
11.6.4	Actuation and Use.....	478
12	Typical Designs of Vehicle Transmissions.....	479
12.1	Passenger Car Transmissions	479
12.1.1	Manual Passenger Car Transmissions (MT)	481
12.1.2	Automated Manual Passenger Car Transmissions (AMT).....	494
12.1.3	Dual Clutch Passenger Car Transmissions (DCT).....	498
12.1.4	Automatic Passenger Car Transmissions (AT)	503
12.1.5	Passenger Car Hybrid Drives	511
12.1.6	Continuously Variable Passenger Car Transmissions (CVT) ..	514
12.2	Commercial Vehicle Transmissions	520
12.2.1	Manual Commercial Vehicle Transmissions (MT).....	521
12.2.2	Automated Manual Commercial Vehicle Transmissions (AMT).....	530
12.2.3	Commercial Vehicle Torque Converter Clutch Transmissions (TCCT).....	538
12.2.4	Automatic Commercial Vehicle Transmissions (AT).....	542
12.2.5	Commercial Vehicle Hybrid Drives.....	546

12.2.6	Continuously Variable Commercial Vehicle Transmissions (CVT).....	547
12.3	Final Drives	548
12.3.1	Axle Drives for Passenger Cars.....	549
12.3.2	Axle and Hub Drives for Commercial Vehicles.....	551
12.3.3	Differential Gears and Locking Differentials.....	555
12.4	All-Wheel Drives, Transfer Gearboxes	560
13	Electronic Transmission Control	573
13.1	Networked Systems	573
13.2	Electronic Transmission Control Unit (TCU).....	574
13.2.1	TCU Structure	575
13.2.2	Operating Conditions and Construction Technologies.....	576
13.3	Control Systems.....	577
13.3.1	Transmission Actuator	579
13.3.2	Clutch Actuator	579
13.3.3	Transmission Control Functions	580
13.3.4	Software	584
13.3.5	Further Examples of Transmission Control Systems	585
13.4	Transmission Calibration with Vehicle-Specific Software Data Input.....	587
14	Computer-Aided Transmission Development	589
14.1	Principles and Tools	590
14.2	Driving Simulation	594
14.2.1	Simulation of Vehicle Longitudinal Dynamics	595
14.2.2	Route Data Set, Route Data Acquisition	599
15	The Automotive Transmission Development Process.....	600
15.1	Product Life Cycle.....	601
15.2	Product Strategy, Product Planning	603
15.3	Release Stages in the Product Development Process.....	604
15.4	The Design Process and Systematic Design	606
16	Transmission Manufacturing Technology.....	615
16.1	Process Chains for Steel Part Processing.....	616
16.1.1	Soft Machining Methods.....	617
16.1.2	Heat Treatment Methods.....	617
16.1.3	Hard Machining Methods.....	617
16.2	Process Chains for Cast Part Processing.....	618
16.2.1	Casting Methods.....	619
16.2.2	Machining Cast Parts	620
16.3	Process Chains for Gear Machining	621
16.3.1	Soft Machining Methods.....	621
16.3.2	Hard Machining Methods.....	623
16.4	Process Chains for Sheet Metal Machining	623

16.4.1 Sheet Separation.....	624
16.4.2 Sheet Forming.....	625
16.5 Manufacturing and Factory Management.....	626
16.5.1 Work Preparation and Planning.....	626
16.5.2 Production Systems.....	626
16.5.3 Statistical Process Control in Manufacture.....	627
17 Reliability and Testing of Automotive Transmissions.....	631
17.1 Principles of Reliability Theory.....	632
17.1.1 Definition of Reliability.....	632
17.1.2 Statistical Description and Representation of the Failure Behaviour of Components.....	633
17.1.3 Mathematical Description of Failure Behaviour using the Weibull Distribution.....	636
17.1.4 Reliability with Systems.....	641
17.1.5 Availability of Systems.....	642
17.2 Reliability Analysis of Vehicle Transmissions.....	643
17.2.1 System Analysis.....	644
17.2.2 Qualitative Reliability Analysis.....	646
17.2.3 Quantitative Reliability Analysis.....	648
17.3 Testing to Ensure Reliability.....	651
17.3.1 Classifying Vehicle Transmission Test Programs.....	653
17.3.2 Test Benches for the Test Programs.....	656
17.3.3 Simulation during Bench Testing.....	658
References.....	661
Index of Companies/Transmissions.....	695
Index of Names.....	698
Subject Index.....	699
About the Authors.....	717

Terms and Symbols

A formula you cannot derive is a corpse in the brain /C. Weber/

Physical variables are related by mathematical formulae. These can be expressed in two different ways:

- quantity equations,
- unit equations.

Quantity equations

Quantity equations are independent of the unit used, and are of fundamental application. Every symbol represents a physical quantity, which can have different values:

Value of the quantity = numerical value \times unit .

Example: Power P is generally defined by the formula

$$P = T \omega, \quad (1)$$

where T stands for torque and ω stands for angular velocity.

Unit equations

If an equation recurs frequently or if it contains constants and material values, it is convenient to combine the units, in which case they are no longer freely selectable.

In unit equations, the symbols incorporate only the numerical value of a variable. The units in unit equations must therefore be precisely prescribed.

Example: In order to calculate the effective power P in kW at a given rotational speed n in 1/min, the above equation (1) becomes the unit equation

$$P = \frac{T n}{9550}. \quad (2)$$

The unit equation (2) applies where the prescript P is expressed in kW, T in Nm and n in 1/min.

Designation system for steels

In several sections of this book, particular steels have been referred to according to German standard DIN EN 10027. Often there is no exact English equivalent. However it seemed important to provide an explanation of the type of steel being referred to. Therefore the basics of the specification will be explained.

The main symbol is the carbon content multiplied by 100 followed by the chemical composition of the material. The alloying elements are sorted by their alloy content, whereby the percentage of content is multiplied by a multiplier according to the following table. If there is no percentage of an element given in the specification, this means that there is just a small content of this element.

Multiplier	Alloying element
4	Mn, Si, Ni, W, Cr, Co
10	Al, Cu, Mo, Ta, Ti, V, Pb, Zr, Nb, Be
100	P, S, N, C
1000	B

Examples:

16MnCr5 0.16% carbon, 1.25% Cr, small content of Cr
 42CrNiMo4-4 0.42% carbon, 1% Cr, 1% Ni, small content of Mo

Terms and Symbols

(Only those which occur frequently; otherwise see text)

A	Surface area, vehicle cross-section = projection of vehicle frontal area
A_R	Friction surface area
$A(t)$	Availability
B_{10}	System service life for a failure probability of 10%
B_x	System service life for a failure probability of x%
C	Basic dynamic load rating, constant
CG	Constant gear
CG_H	Front-mounted splitter unit constant high
CG_L	Front-mounted splitter unit constant low
CG_{main}	Main gearbox constant gear
CG_R	Range-change unit constant gear
D	Diameter, damage
D_{act}	Actual damage sum

D_{prof}	Damage sum of a load profile
D_{th}	Theoretical damage sum
E	Modulus of elasticity
F	Force
F_{B}	Braking force
F_{H}	Manual effort, slope descending force
F_{L}	Air resistance, bearing force
F_{Q}	Shear force (transverse force)
F_{R}	Wheel resistance
F_{S}	Lateral force
F_{St}	Gradient resistance
F_{U}	Circumferential force
F_{Z}	Traction
$F_{\text{Z,A}}$	Available traction
$F_{\text{Z,B}}$	Required traction
F_{a}	Acceleration resistance, axial force
F_{ax}	Pressure force of the pressure plate
F_{n}	Normal force
F_{r}	Radial force
F_{t}	Tangential force
$F(t)$	Distribution function, failure probability
G_{R}	Wheel load
J	Moment of inertia
K_{G}	Transmission characteristic value
L	Service life, sound level
M_{b}	Bending moment
M_{t}	Torsional moment
M_{v}	Reference moment
N	Number of load cycles, number of oscillation cycles to failure, component service life
P	Power, equivalent bearing load
P_{A}	Frictional power related to surface area
$P_{\text{Z,B}}$	Power requirement at wheel
P_{m}	Mean frictional power during synchronizer slipping
Q	Shear force (transverse force), flow rate
R	Reaction force, stress ratio
R_{e}	Yield strength
R_{m}	Tensile strength
$R_{\text{p0.2}}$	0.2% offset yield strength
$R(t)$	Survival probability, reliability
S	Safety factor, locking safety factor of synchronizers, slip, interlock value, taper disc radius
S_{B}	Brake slip
S_{H}	Rear-mounted splitter unit high
S_{L}	Rear-mounted splitter unit low
S_{T}	Drive slip

T	Torque, temperature, characteristic service life
T_B	Acceleration torque (synchronizer), locking torque (differential)
T_C	Clutch torque
T_D	Drag torque
T_L	Load torque
T_M	Engine torque
T_R	Friction torque, slip torque
T_Z	Opening torque (synchronizer)
U	Revolutions
V	Displacement volume (oil pump)
V_H	Total swept volume
W	Section modulus, work, absorbable work, frictional work
W_A	Frictional work related to surface area (specific frictional work)
W_b	Section modulus under bending
W_t	Section modulus under torsion
a	Acceleration, centre distance
b	Shape parameter, failure slope, pack length, width, fuel consumption
b_0	Size factor
b_e	Specific fuel consumption
b_s	Fuel consumption per unit of distance, surface factor
c	Rigidity, absolute speed
c_w	Drag coefficient
c_m	Machine capability index
c_p	Process capability index
c_s	Tooth rigidity
c_u	Circumferential component of absolute speed
c_γ	Meshing rigidity (average value of tooth rigidity over time)
d	Diameter
e	Eccentricity
f	Deflection, frequency
f_R	Rolling resistance coefficient
$f(t)$	Density function
g	Gravitational acceleration
h_i	Number of stress oscillation cycles
i	Ratio
i_A	Powertrain ratio (from engine to wheels)
i_{CG}	Constant gear ratio
i_E	Final ratio
$i_{E,A}$	Ratio of the axle drive
$i_{E,N}$	Ratio of the hub drive
$i_{E,V}$	Ratio of the transfer box
i_G	Transmission ratio
$i_{G,tot}$	Overall gear ratio, range of ratios
i_S	Moving-off element ratio

i_V	Variator ratio
j	Number of friction surfaces
k	Wöhler curve equation exponent
$k(v)$	Characteristic value of a torque converter
m	Gear module, mass, linear scale (converter)
m_F	Vehicle mass
m_n	Standard module
n	Rotational speed, number, number of load cycles, number of bearings
n_M	Engine speed
p	Contact pressure, pressure, number of gear pairs, service life exponent
p_{me}	Effective average pressure in the cylinder of a combustion engine
q	Gradient
q'	Gradient in %
r	Radius, redundancy level of a system
r_{dyn}	Dynamic wheel radius
s	Travel, shift movement at the gearshift sleeve
s_{Fn}	Root thickness chord
t	Statistical variable, time
t_0	Failure free time
t_R	Slipping time, friction time
t_S	Shifting time
u	Gear ratio, circumferential speed
v	Speed, flow rate
v_F	Vehicle speed
v_W	Wind speed
v_{th}	Theoretical speed with slip $S = 0$
w	Absorbed work
x	Addendum modification coefficient
x, y, z	Co-ordinates
z	Number of speeds, number of friction surfaces, number of teeth, number of load cycle passes
z_i	Number of teeth gear i
Δ	Interval, difference
ΔS	Wear path (synchronizer)
ΔV	Wear (synchronizer)
α	Meshing angle, cone angle of a cone synchronizer, viscosity-pressure coefficient
α_0	Effort ratio
α_{St}	Gradient angle
α_k	Stress concentration factor
α_n	Normal meshing angle
β	Helix angle at reference circle, opening angle of dogs

β_k	Fatigue notch factor
δ	Reference cone angle, degree of pump irregularity (volumetric flow pulsation)
ε	Total contact ratio
ε_α	Transverse contact ratio
ε_β	Overlap ratio
η	Efficiency, dynamic viscosity
ϑ	Temperature
λ	Performance coefficient (converter, retarder), rotational inertia coefficient
$\lambda(t)$	Failure rate
μ	Torque ratio, torque conversion, coefficient of friction
μ_{stall}	Stall torque ratio
μ_H	Static coefficient of friction
ν	Speed ratio, speed conversion, kinematic viscosity
ρ	Density, radius of curvature
σ	Normal stress
σ_D	Endurance strength
σ_H	Hertzian stress
σ_b	Bending stress
σ_v	Reference stress
τ	Torsional stress, torque increase of a combustion engine
φ	Gear step, bending angle
φ_1	Base ratio change with progressive stepping
φ_2	Progression factor with progressive stepping
φ_{th}	Gear step with geometrical stepping
ω	Angular velocity

Subscripts

0	Nominal or initial state
1	Pinion (= small gearwheel), input
2	Wheel (= large gearwheel), output
3	Frame
1, 2, 3, ...	At point 1, 2, 3, ...
A	Available, related to area, powertrain, axle
AM	Angular momentum
B	Required, brake, acceleration
C	Clutch
CC	Converter lock-up clutch
CG	Constant gear
CS	Countershaft
D	Endurance, endurance strength, deficit, direct, drag

E	Final ratio
Ex	Excess
F	Vehicle, tooth root
G	Gearbox, propeller shaft
H	Static friction, main, main gearbox, ring gear, high (= fast), Hertzian, displacement, manual
IS	Input shaft
L	Air, load, low (= slow)
L, L1, L2	At bearing point, at bearing point 1, 2
M	Engine, model
MS	Main shaft
MSW	Main shaft wheel
N	Hub, rear-mounted range unit
OS	Output shaft
P	Pump, pump wheel, planetary gear
PV	Pump test
Q	Transverse
R	Reverse gear, roll, slip, friction, wheel, range-change unit, reactor, rotor (retarder)
Roll	Roll
Rot	Rotation
S	Sun gear, splitter unit, stator (retarder), system, lateral, shifting, moving-off element
Sch	Pulsating (strength)
St	Gradient
T	Turbine, drive
TC	Torque converter
U	Circumferential
V	Front-mounted range unit, loss, test, variator, transfer box
W	Alternating (strength), wind
Z	Traction, opening
a	Acceleration, axial, values at tip circle
abs	Absolute
act	Actual
ax	Axial
b	Bending
calc	Calculated
dyn	Dynamic
e	Effective
exper	Experimental
f	Values at root circle
i	Inner, input, control variable $i = 1, 2, 3, \dots, n$
i, j	At point i, j
id	Ideal
in	Input

j	Control variable
k	Control variable, notching effect
m	Mean, machine, number of stress classes
main	Main
max	Maximum
min	Minimum
n	Nominal, normal, n-th gear, standard
o	Outer, output
out	Output
p	Process
perm	Permissible
r	Radial
red	Reduced
ref	Reference
rel	Relative
res	Resultant
s	Surface, distance
spec	Specific
stat	Static
t	Torsion, time, tangential
th	Theoretical
tot	Total
trans	Transverse
u	Circumferential
v	Reference
w	Pitch circle
x, y, z	In x, y, z direction, around x, y, z axis
z	Highest gear, number of speeds

1 Introduction

Every vehicle needs a transmission!

1.1 Preface

All vehicles, aircraft and watercraft included, require transmissions in order to convert torque and engine speed. Transmissions are distinguished in accordance with their function and purpose – e.g. selector gearboxes, steering boxes and power take-offs. This book deals exclusively with transmissions for road vehicles as well as for vehicles designed for both on-road and off-road use (Figure 1.1).

Figure 1.2 provides an overview of common transmission designs and their systematic classification. Further details can be found in Chapter 6 “Vehicle Transmission Systems”. Dual clutch transmissions are assigned to automatic transmissions with various gear ratios due to their similarity with respect to control and functionality.

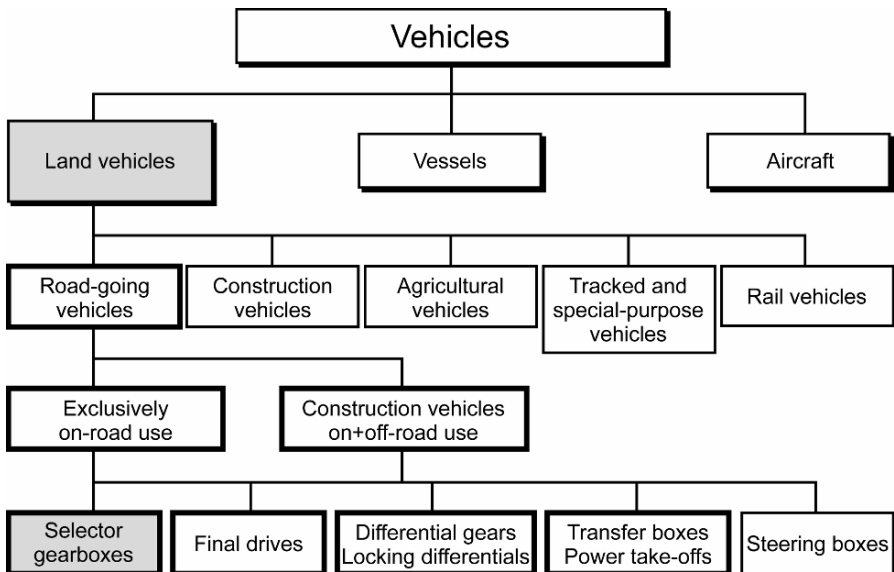


Fig. 1.1. Definition of the term “automotive transmission” as this book uses it

Transmission types												
z-speed transmissions (geared transmissions with z speeds)									Continuously variable transmissions (CVT)			
Manual transmissions (MT)		Automated manual transmissions (AMT)		Automatic transmissions with various gear ratios			Hybrid drive with electric machines			Mechanical		Hydraulic
Constant-mesh transmission	Synchromesh transmission	Semi-automated constant-mesh or synchromesh trans.	Fully automated constant-mesh or synchromesh trans.	Dual clutch transmission (DCT)	Automatic transm., countershaft type	Conventional automatic transm. (AT)	Serial hybrid	Parallel hybrid	Power-split hybrid	Pulley transmission	Toroidal transmission	Hydrostatic transmission
With power interruption				Without power interruption (powershift)								
Moving-off with foot-operated clutch				Automatic moving-off								
Manual gearshift		Automatic gearshift					Automatic torque and speed conversion					

Fig. 1.2. Systematic classification of automotive transmission types

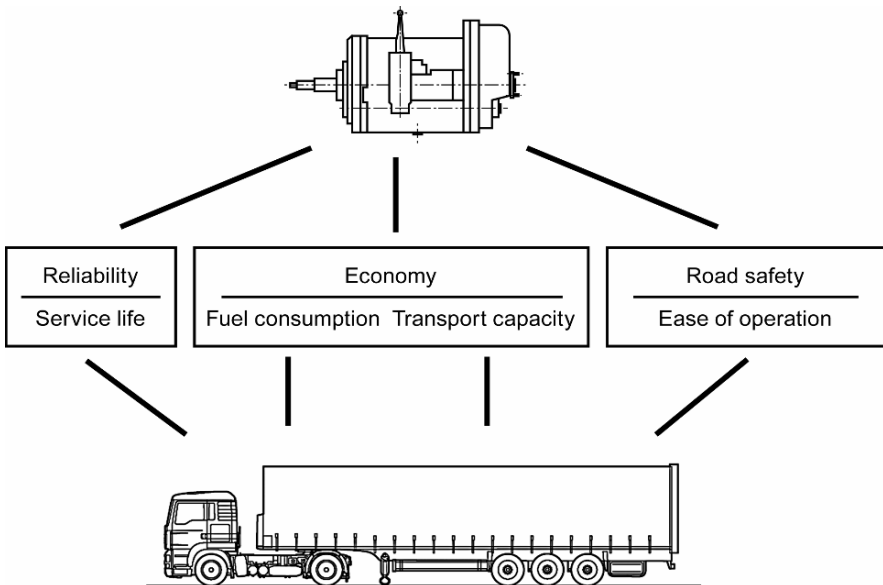


Fig. 1.3. The effect of the transmission on basic attributes of a vehicle

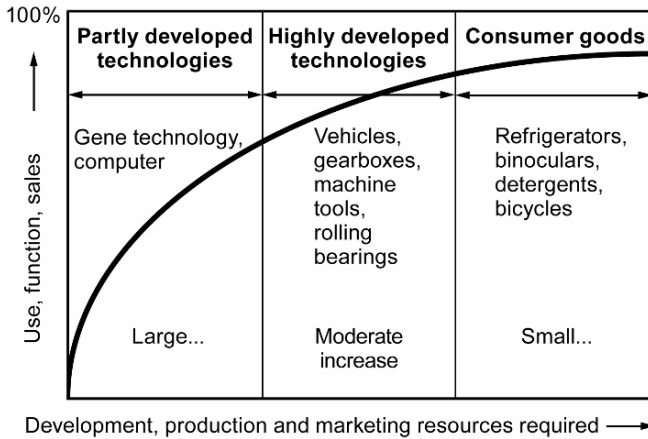
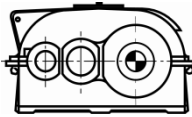
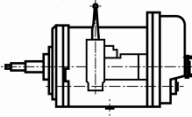
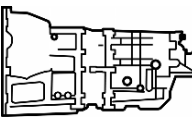


Fig. 1.4. Achievable increase in the practical value of a product by additional development effort

The task of a transmission is to convert the traction available from the drive unit, satisfying requirements placed on it by the vehicle, the road, the driver and the environment. Technical and economical competitiveness are essential here. In addition to the driving and transport performance of passenger and commercial vehicles, transmissions are of central importance with respect to reliability, fuel consumption, ease of operation and road safety (Figure 1.3).

Table 1.1. Comparison between industrial and automotive transmissions

Transmission	Number of speeds (forward)	Ratio 1st gear/overall gear ratio	Power (kW)	Input torque (Nm)	Mass (kg)	Specific power (kW/kg)
 Industrial	1	12.5 —	330	2100	680	0.48 100%
 Commercial vehicle (AMT)	16	14.1 17.0	397	2600	266	1.49 300%
 Passenger car (MT)	6	4.2 5.1	294	500	46	6.39 1300%

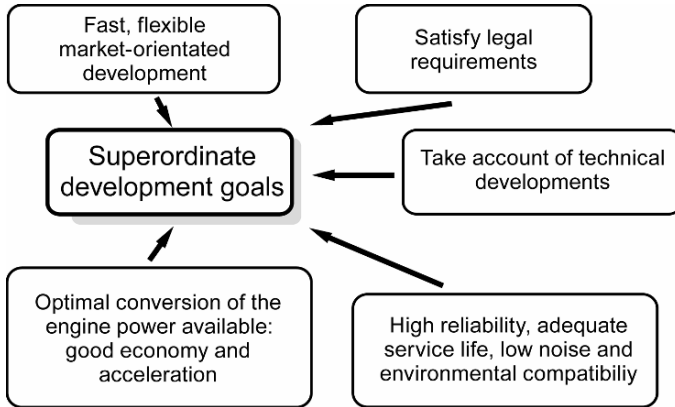


Fig. 1.5. Superordinate development goals for vehicle transmissions

Automotive transmissions are mass-produced products of a high technical and technological order. They are classified as highly developed technologies (Figure 1.4). What is remarkable is the specific power P_{spec} in kW/kg of commercial vehicle transmissions, which is more than three times more than that of industrial transmissions (Table 1.1), despite the fact that automotive transmissions have more speeds. On the other hand, industrial transmissions have to be designed for a longer service life.

Basic innovations in the field of automotive transmissions are no longer to be expected. Instead, we are witnessing a process of gradual evolution. This process is characterized by system thinking focused on the factors Environment \leftrightarrow Traffic \leftrightarrow Vehicle \leftrightarrow Engine/Transmission and by the use of electronics for operational, control and monitoring processes. The superordinate design objectives for automotive transmissions resulting from these tendencies are shown in Figure 1.5.

Vehicle transmission development must be fast and market-oriented. Customers' preferences, especially in the case of commercial vehicles, must be accommodated flexibly. Legal conditions, kW/t-regulation or emission policies for example, must be met. Furthermore, emotional aspects like driving pleasure must also be taken into consideration.

The main goal when designing an automotive transmission is an optimal conversion of the traction available from the engine into the traction force of the vehicle over a wide range of road speeds. This must be done such that there is a favorable compromise between the number of speeds, the climbing and acceleration performance and fuel consumption. Further technical and technological developments should obviously be considered – reliability and service life as well. It is also essential to have regard for environmental and social considerations.

The design of vehicle transmissions should always stay within the planning horizon for new vehicles (Figure 1.6). During the developmental phase of a vehicle, a corresponding transmission must also be created or further developed. To this end, new manufacturing technologies for mass production must also be prepared and introduced.

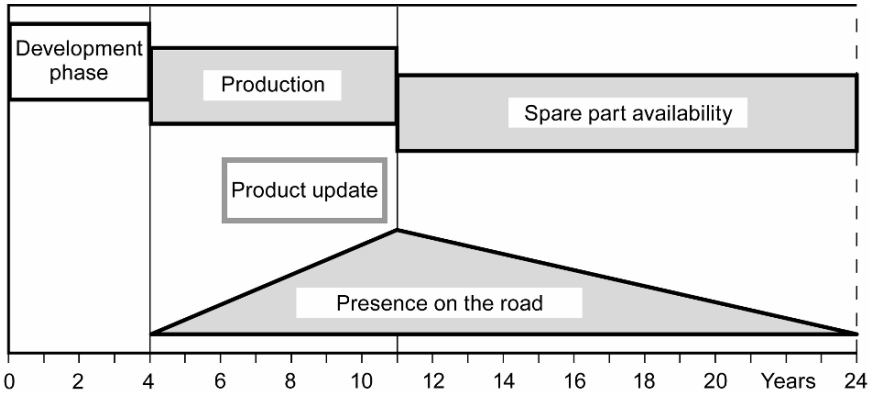


Fig. 1.6. Time dimensions and planning horizons in the automotive industry, from [1.1]

After the end of the production phase, it should be guaranteed that spare parts are available. For this purpose, the life cycles of additional components, including semiconductor components, have to be taken into consideration.

This book seeks to present the automotive transmission development process as a whole (Figure 1.7). It should show ways of thinking that go beyond mere component design. Regardless of which product is at hand, it is always necessary to assess the total system in which that product will later be employed. Such a system overview is indispensable and will be presented in Chapter 2.

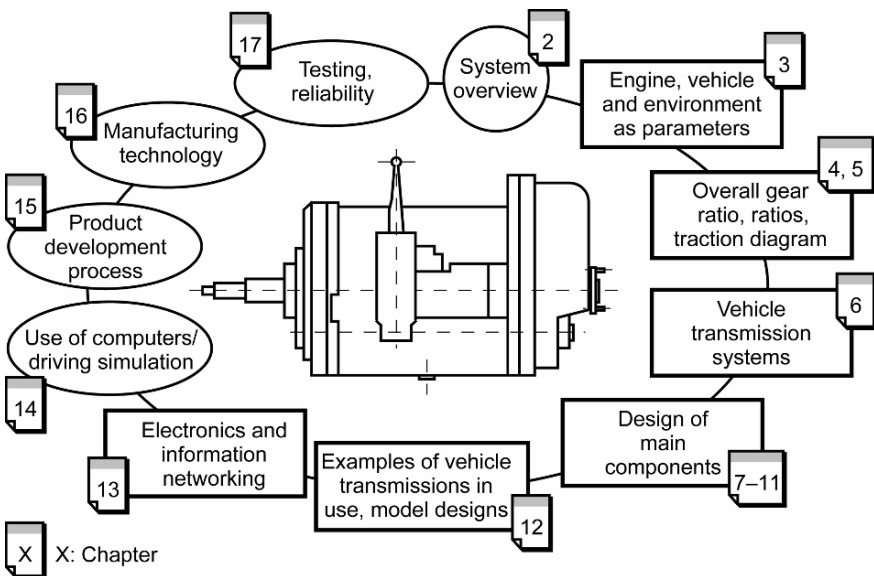


Fig. 1.7. The tasks involved in developing automotive transmissions, overview of chapters

Automotive transmissions are decisively influenced by the vehicle, the engine and the road profile. Without basic knowledge of these factors, meaningful developments are impossible.

Chapter 3 shows the interaction between power required and power available. The first development task focused directly on vehicle transmission is then selecting the range of ratios to be covered, the “overall gear ratio”. In conjunction with selecting the number of speeds z , the gear ratio of the individual speeds, the resultant gear steps and the gear ratio of the final drive, the interaction of the vehicle and its transmission system can be evaluated and defined. Observing the road profile, it must be decided whether the vehicle is being sufficiently accelerated and whether the required climbing power and the specified maximum speed v_{\max} are reached. We can then establish at the same time whether the transmission unit also permits economical driving – driving with low amounts of fuel consumption in particular. This is dealt with extensively in Chapters 4 and 5.

Creative design, which is indispensable, is complemented by systematic design. Here, a functional analysis is carried out during the conceptual phase. Solutions for individual functions must be found, evaluated and joined together to make an overall solution, i.e. the transmission design. Chapter 6 provides the information regarding the vehicle transmission systems necessary for this.

Following this in Chapters 7 to 11 are the layout and design of the most important components of a transmission: gearwheels, shafts, bearings, synchronizers, clutches, parking locks, pumps as well as hydrodynamic clutches and converters. A treatment of all the details involved in highly developed computation and simulation methods would go beyond the scope of this book. We have instead confined ourselves to the basics of calculation methodology and operations.

In Chapter 12, the structure of various transmission designs and important detailed solutions are explained with the help of a plentiful amount of design examples. Electronic transmission controls built with microprocessors have been the standard in automatic transmissions since 1982. They are among the most complex electronic components in the vehicle and are undergoing a very dynamic development with respect to both hardware and software. Chapter 13 explores this topic and deals with their integration and interconnection with other control devices in the vehicle.

Tools and parameters for the development of automotive transmissions are handled in the latter part of the book. Chapter 14 is dedicated to calculation and simulation tools. In Chapter 15, we take a look at the product development process. Manufacturing technology has a large influence on transmission design, competitiveness and quality. Chapter 16 provides insight into the broad and innovative field of machining, assembly and final inspection.

Quality is a decisive competitive factor. The final customers are interested above all in the reliability and service life of the overall system. Methods for planning and guaranteeing quality as well as corresponding testing programs and test stations are described in Chapter 17.

Of particular concern in this book is to show the reader different approaches and to supply data as amply as possible regarding practical development work on automotive transmissions. As Dudeck put it, “The task of engineering science is,

among other things, to refine complicated models to the point of simplicity". This book strives towards that aim.

1.2 History of Automotive Transmissions

Knowledge of the past and of the state of the Earth adorns and nourishes the human spirit /Leonardo da Vinci/

Learn from the past for the future! Development engineers and designers should have a grasp of the historical development of their products. Then they can estimate what progress is still possible and what technological potential the current product development has already realized. Such knowledge compliments that of systematic design (see Chapter 15).

1.2.1 Basic Innovations

Basic innovations are discoveries, inventions and new developments, without which products of today could not have been developed. They lead in turn to further discoveries, inventions, new developments and designs that culminate inevitably in new products (Figure 1.8).

In the course of such developments, certain phenomena should be explained and researched in order to guarantee that the product will function reliably.

Table 1.2. Examples of fundamental innovations in automotives and automotive transmissions

4000 BC	Mesopotamian vase with a picture of a cart	1829	<i>Stephenson</i> Rail vehicle, steam locomotive
2500 BC	Wheels made of two semicircular wooden discs, presumably with leather tyres	1877	<i>Otto</i> Patent for four-stroke gas engine with compression
2000–1000 BC	Spur gears with pin wheel gear as drive element for water scoops (Sakie, Figure 1.10), worm gears for cotton gins	1885	<i>Benz</i> Three-wheeler with internal combustion engine
500 BC	Greek scholars discover the principles of mechanics	1897	<i>Bosch</i> Magneto-electric ignition
200 BC	Lever, crank, roller, wheel, hoist, worm gear and gearwheel are in use	1905	<i>Föttinger</i> Hydrodynamic torque converter
1754	<i>Euler's</i> law of gears for gearwheels, involute toothing	1907	<i>Ford</i> Mass production of model T; the passenger car becomes a mass-produced item
1769	<i>Watt</i> Patent for steam engine	1923	<i>Bosch</i> Injection pump
1784	<i>Watt</i> Gearbox with constant-mesh engagement	1925	<i>Rieseler</i> Automatic passenger car transmission with torque converter and planetary gear set