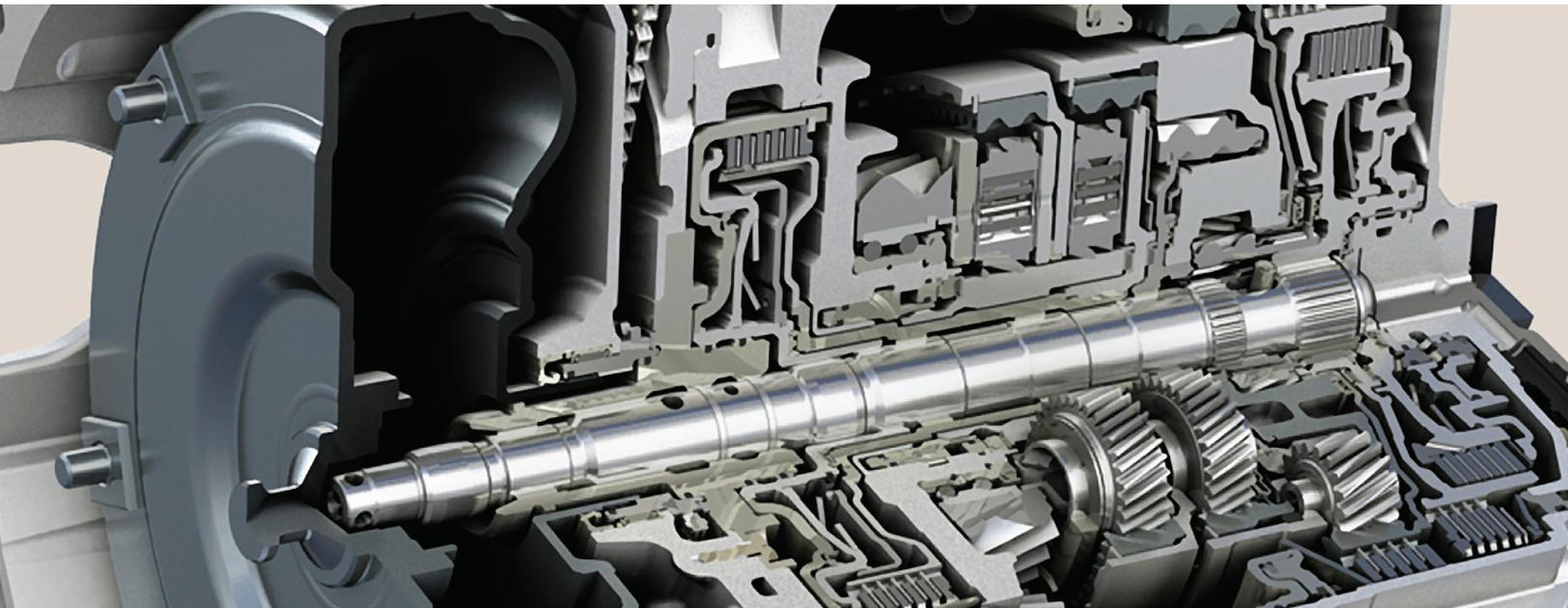


Design Practices

# Passenger Car Automatic Transmissions



Fourth Edition

**SAE** *International*<sup>®</sup>

Sponsored by

**Lubrizol**

# Contents

<b>Foreword</b>	<b>xi</b>
<b>Preface to the Fourth Edition</b>	<b>xv</b>
<b>CHAPTER 1 Transmission Cases and Parking Mechanisms</b>	<b>1-1</b>
<b>1.1 Transmission Cases</b>	<b>1-1</b>
<i>C. E. Shellman with updates by Ernest DeVincent</i>	
<b>1.2 Parking Mechanisms</b>	<b>1-10</b>
<i>A. Gupta</i>	
<b>CHAPTER 2 Torque Converters and Start Devices</b>	<b>2-1</b>
<b>2.1 Fluid Couplings</b>	<b>2-1</b>
<i>J. W. Qualman and E. L. Egbert</i>	
<b>2.2 Multiturbine Torque Converters</b>	<b>2-17</b>
<i>F. H. Walker</i>	
<b>2.3 Application of Hydrodynamic Drive Units to Passenger Car Automatic Transmissions</b>	<b>2-31</b>
<i>E. W. Upton</i>	
<b>2.4 Design of Single-Stage, Three-Element Torque Converter</b>	<b>2-49</b>
<i>V. J. Jandasek</i>	
<b>2.5 Technology Needs for the Automotive Torque Converter—     Part 1; Internal Flow, Blade Design, and Performance</b>	<b>2-70</b>
<i>Robert R. By and John E. Mahoney with updates by Thomas G. Brand</i>	
<b>2.6 An Experimental Analysis of Fluid Flow in a Torque Converter</b>	<b>2-85</b>
<i>Akio Numazawa, Fumihiko Ushijima, Kagenori Fukumura, and Tomo-o-Ishihara</i>	
<b>2.7 A Loss Analysis Design Approach to Improving Torque Converter Performance</b>	<b>2-93</b>
<i>Masaaki Kubo and Eiji Ejiri</i>	
<b>2.8 The Chrysler Torque Converter Lock-Up Clutch</b>	<b>2-103</b>
<i>A. P. Bloomquist and S. A. Mikel with updates by Thomas G. Brand</i>	
<b>2.9 Control Technology of Minimal Slip-Type Torque Converter Clutch</b>	<b>2-117</b>
<i>Takeo Hiramatsu, Takao Akagi, and Haruaki Yoneda</i>	

2.10	<b>Dynamic Behavior of a Torque Converter with Centrifugal Bypass Clutch</b>	2-125
	<i>M. C. Tsangarides and W. E. Tobler</i>	
<b>CHAPTER 3</b>	<b>Gears, Splines, and Chains</b>	<b>3-1</b>
3.1	<b>Design of Planetary Gear Trains</b>	3-2
	<i>O. K. Kelley, with updates by E. L. Jones and M. T. Berhan</i>	
3.2	<b>Transmission Gear Design for Strength and Surface Durability</b>	3-8
	<i>E. L. Jones, with updates by E. L. Jones, M. T. Berhan, H. Dourra, and M. B. Leising</i>	
3.3	<b>Manufacturing Considerations Affecting Transmission Gear Design</b>	3-17
	<i>A. Hardy, with updates by R. J. Garrett</i>	
3.4	<b>Gear Design for Noise Reduction</b>	3-25
	<i>W. D. Route, with updates by E. L. Jones, D. K. Ducklow, and M. T. Berhan</i>	
3.5	<b>The Lever Analogy</b>	3-40
	<i>H. L. Benford and M. B. Leising, with updates by M. B. Leising, H. Dourra, and M. T. Berhan</i>	
3.6	<b>Design Practice for Automotive Driveline Splines and Serrations</b>	3-50
	<i>W. B. McCardell, J. Mahoney, and D. Cameron, with updates by D. Cameron, E. L. Jones, and C. E. Dieterle</i>	
3.7	<b>The Effective Fit Concept of Involute Splines and Inspection</b>	3-68
	<i>L. De Vos, with updates by C. E. Dieterle and M. T. Berhan</i>	
3.8	<b>Chain Drives in the Vehicle Powertrain</b>	3-75
	<i>R. H. Mead, T. O. Morrow, and R. G. Young, Jr., with updates by M. Giovannini, R. G. Young, Jr., and M. T. Berhan</i>	
3.9	<b>The Gemini Phased Chain System: A New Tool in Automotive Power Transmission</b>	3-86
	<i>P. Mott and B. Martin</i>	
<b>CHAPTER 4</b>	<b>Transmission Shaft Fatigue Design</b>	<b>4-1</b>
	<i>Jeffrey K. Baran and Keith D. VanMaanen</i>	
4.1	<b>Abstract</b>	4-1
4.2	<b>Introduction</b>	4-1
4.3	<b>Nomenclature</b>	4-2
4.4	<b>Stress Calculation</b>	4-2
4.5	<b>Mass Relationship</b>	4-3
4.6	<b>Stress Concentration</b>	4-3
4.7	<b>Fatigue Properties (S-N Curve)</b>	4-4
4.8	<b>S-N Modifying Factors</b>	4-5

---

4.9	Loading Conditions	4-8
4.10	Combined Loading	4-8
4.11	Summary	4-11
4.12	References	4-11
4.13	Bibliography	4-11
4.14	Appendix A—Stress Concentration Factors	4-12
4.15	Appendix B—Example Problems	4-18
<b>CHAPTER 5</b>	<b>Bearings</b>	<b>5-1</b>
5.1	Design of Sleeve Bearings and Plain Thrust Washers <i>L. J. Pesek and W. E. Smith</i>	5-1
5.2	Improving the Performance of Sleeve Bushings and Thrust Washers <i>Brad L. Blaine and Christopher D. Wiegandt</i>	5-20
5.3	The Use of Polymeric Thrust Elements in Powertrain Applications <i>R. G. Van Ryper</i>	5-26
5.4	Rolling Element Bearings in Light Vehicle Automatic Transmissions <i>J. R. Hull, with updates by M. D. Myers</i>	5-30
5.5	Design and Selection Factors for Automatic Transaxle Tapered Roller Bearings <i>B. Martin and H. E. Hill</i>	5-66
<b>CHAPTER 6</b>	<b>Friction Clutches</b>	<b>6-1</b>
	<i>Robert C. Lam, Donn K. Fairbank, Keith Martin, Anthony J. Grzesiak, and Ted D. Snyder</i>	
6.1	Evolution of High-Energy Wet Friction Materials	6-2
6.2	Multi-Plate Friction Clutch	6-8
6.3	Bands	6-30
6.4	References	6-44
<b>CHAPTER 7</b>	<b>One-Way Clutches</b>	<b>7-1</b>
	<i>Updated by John M. Kremer</i>	
7.1	Roller One-Way Clutches	7-2
7.2	Sprag One-Way Clutches	7-29
7.3	Pawl One-Way Clutches	7-49

<b>CHAPTER 8</b>	<b>Automatic Transmission Controls</b>	<b>8-1</b>
8.1	<b>Introduction</b> <i>Maurie Leising</i>	8-2
8.2	<b>Basic Shift Processes—The “How of Shifting”</b> <i>M. Leising, Hussein Dourra, and Gang Chen</i>	8-2
8.3	<b>Shift Torque Analysis and the Continuously Variable Transmission</b> <i>John E. Mahoney, Joel M. Maguire, and Shushan Bai</i>	8-21
8.4	<b>Shift Scheduling</b> <i>Gang Chen and M. Leising</i>	8-26
8.5	<b>Transmission Control and Types of Controls</b> <i>Ronald Cowan, Charles Marshall, and M. Leising</i>	8-40
8.6	<b>Transmission Operational Features</b> <i>Ronald Cowan, Charles Marshall, and M. Leising</i>	8-44
8.7	<b>Automatically Shifted Manual Transmissions</b> <i>M. Leising, G. Chen, and H. Dourra</i>	8-47
8.8	<b>Control Components</b> <i>John Titlow and Joseph Gierut</i>	8-65
8.9	<b>Development Technology</b> <i>Hussein Dourra and Ronald Cowan</i>	8-112
<b>CHAPTER 9</b>	<b>Automatic Transmission Pump Design</b> <i>T. Roeber, M. Goulet, P. Dion, and Glenn B. Mann</i>	<b>9-1</b>
9.1	<b>Introduction</b>	9-2
9.2	<b>Types of Pumps</b>	9-2
9.3	<b>Types of Pumping Systems</b>	9-2
9.4	<b>Pump Design Guidelines</b>	9-2
9.5	<b>Survey of Transmission Pumps Currently in Use</b>	9-11
9.6	<b>What is Coming?</b>	9-12
9.7	<b>References</b>	9-12
<b>CHAPTER 10</b>	<b>Seals and Gaskets</b>	<b>10-1</b>
10.1	<b>An Overview of Automatic Transmission Gaskets</b> <i>Andrew F. Joseph, Jeff Nelson, and Lane Noble</i>	10-2
10.2	<b>An Overview of Transmission Radial Shaft Seals</b> <i>Susan M. Bothe and Jeff Dieterle</i>	10-13

---

<b>CHAPTER 11</b>	<b>Transmission Temperature Control and Lubrication</b>	<b>11-1</b>
11.1	<b>Introduction</b> <i>Maurie Leising and Charles Redinger</i>	11-1
11.2	<b>Transmission Cooling Systems: Oil-to-Water Type</b> <i>E. F. Farrell and T. M. Wang</i>	11-2
11.3	<b>Transmission Cooling Systems: Air Cooling</b> <i>M. G. Gabriel</i>	11-10
11.4	<b>Temperature Effects on Transmission Operation</b> <i>T. J. Griffen</i>	11-20
11.5	<b>Temperature Control and Fuel Consumption</b> <i>M. Leising and C. Redinger</i>	11-27
11.6	<b>Design and Validation of Automatic Transmission Lubrication Circuits</b> <i>James T. Gooden</i>	11-30
<b>CHAPTER 12</b>	<b>ATF and Driveline Fluids</b>	<b>12-1</b>
	<i>Craig Tipton, Tze-Chi Jao, and Timothy Newcomb</i>	
12.1	<b>Introduction</b>	12-2
12.2	<b>History of ATF Development</b>	12-3
12.3	<b>Key Physical Properties</b>	12-5
12.4	<b>Basestocks and Their Impact on Performance</b>	12-8
12.5	<b>Chemical Composition</b>	12-10
12.6	<b>Driveline Fluid Specifications</b>	12-12
12.7	<b>Evaluating the Condition of Used Driveline Oils</b>	12-18
12.8	<b>Future Directions</b>	12-23
12.9	<b>Acknowledgments</b>	12-23
12.10	<b>Glossary of Terms</b>	12-23
12.11	<b>Key References</b>	12-25
<b>CHAPTER 13</b>	<b>Metal Belt Drive Continuously Variable Ratio (CVT) Automatic Transmissions</b>	<b>13-1</b>
	<i>Bruce Anderson</i>	
13.1	<b>Introduction</b>	13-1
13.2	<b>Definitions</b>	13-1
13.3	<b>Application Considerations</b>	13-2
13.4	<b>Belt Design</b>	13-5

13.5	Sheave Design	13-9
13.6	Variator System Considerations	13-11
13.7	Controls Design	13-18
13.8	Fluid	13-20
13.9	References	13-22
13.10	Applicable Publications	13-25
13.11	Appendix A—CVT Cross Sections	13-26
13.12	Appendix B—Transmission Oil Tests	13-27
<b>CHAPTER 14</b>	<b>Automatic Transmission and Transaxle Filter Design</b>	<b>14-1</b>
	<i>Larry Larkin, Andy Boast, Ibrahim Khalil, and Dan Haggard</i>	
14.1	Introduction	14-2
14.2	History	14-2
14.3	Transmission Filter Functions and Requirements	14-2
14.4	Filter Construction	14-5
14.5	Other Design Features That Can Be Built into the Transmission Sump Filter	14-10
14.6	Pressure-Side Filters	14-11
14.7	Transmission Sump Filter Testing	14-13
14.8	References	14-17
<b>Index</b>		<b>I-1</b>