

Contents

1	The internal-combustion engine: an introduction	1
1.1	Heat engines and internal combustion engines	1
1.2	The reciprocating piston engine	3
1.3	Engine operating cycles	4
1.4	Supercharging and turbocharging	6
1.5	Production engine examples	6
1.6	Basic measures	9
1.7	Recommendations for further reading	11
2	Engine maps, customers, and markets	13
2.1	Engine mapping	13
2.2	Automobile, motorcycle, and light-truck applications	17
2.3	Heavy-truck applications	19
2.4	Off-highway applications	21
2.5	Recommendations for further reading	23
3	Engine validation and durability	24
3.1	Developing a durable engine	24
3.2	Fatigue analysis	26
3.3	Friction, lubrication, and wear	33
3.4	Further wear and failure mechanisms	38
3.5	Recommendations for further reading	39
4	Engine development process	41
5	Determining displacement	50
5.1	The engine as an air pump	50
5.2	Estimating displacement	51
5.3	Engine uprating and critical dimensions	55
6	Engine configuration and balance	56
6.1	Determining the number and layout of cylinders	56
6.2	Vibration fundamentals reviewed	57
6.3	Rotating forces and dynamic couples	58
6.4	Reciprocating forces	62
6.5	Balancing the forces in multicylinder engines	65
6.6	Gas pressure forces	69

6.7	Bore-to-stroke ratio optimization	70
6.8	Recommendation for further reading	71
7	Cylinder block and head materials and manufacturing	72
7.1	Block and head materials	72
7.2	Block and head casting processes	75
7.3	A look at block and head casting	78
7.4	Block and head machining processes	80
7.5	Recommendations for further reading	82
8	Block layout and design decisions	83
8.1	Initial block layout	83
8.2	Crankcase design decisions	83
8.3	Cylinder design decisions	91
8.4	Camshaft placement decisions	94
9	Cylinder head layout design	97
9.1	Initial head layout	98
9.2	Combustion chamber design decisions	97
9.3	Valve, port, and manifold design	101
9.4	Head casting layout	108
9.5	Cylinder head cooling	111
9.6	Oil deck design	112
10	Block and head development	113
10.1	Durability validation	113
10.2	High-cycle loading and the cylinder block	113
10.3	Modal analysis and noise	115
10.4	Low-cycle mechanical loads	117
10.5	Block and head mating and the head gasket	118
10.6	Cylinder head loading	120
10.7	Thermal loads and analysis	121
10.8	Recommendations for further reading	123
11	Engine bearing design	125
11.1	Hydrodynamic bearing operation	125
11.2	Split-bearing design and lubrication	127
11.3	Bearing loads	129
11.4	Classical bearing sizing	132
11.5	Dynamic bearing sizing	133
11.6	Bearing material selection	135
11.7	Bearing system validation	138
11.8	Recommendations for further reading	140
12	Engine lubrication	142
12.1	Engine lubricants	142
12.2	Lubrication circuits and systems	145

12.3	Oil pumps	147
12.4	Oil pans, sumps, and windage	149
12.5	Filtration and cooling	150
12.6	Lubrication system performance analysis	151
12.7	Recommendations for further reading	152
13	Engine cooling	153
13.1	Engine cooling circuits	153
13.2	Cooling-jacket optimization	155
13.3	Water pump design	157
13.4	The cooling system	159
13.5	Venting and deaeration	159
13.6	Recommendations for further reading	160
14	Gaskets and seals	162
14.1	Gasketed-joint fundamentals	162
14.2	Engine cover design	164
14.3	Clamping load parameters	165
14.4	Bolt torque and sealing load control	167
14.5	Shaft seal design	168
14.6	Recommendations for further reading	168
15	Pistons and rings	170
15.1	Piston construction	170
15.2	Piston crown and ring land development	172
15.3	Piston pin boss development	175
15.4	Piston skirt development	178
15.5	Piston ring construction	179
15.6	Dynamic operation of the piston rings	181
15.7	Cylinder wall machining	184
15.8	Recommendations for further reading	186
16	Crankshafts and connecting rods	188
16.1	Crankshaft construction and manufacturing	188
16.2	Crankshaft fillet development	189
16.3	Torsional vibration and dampeners	192
16.4	Crankshaft nose development	197
16.5	Crankshaft flange and flywheel development	198
16.6	Connecting-rod construction and development	199
16.7	Recommendations for further reading	200
17	Camshafts and the valve train	202
17.1	Valve train overview	202
17.2	Dynamic system evaluation and cam lobe development	203
17.3	Camshaft durability	208
17.4	Valve train development	210
17.5	Drive system development	214

- 17.6 Future trends in valve train design 215
- 17.7 Recommendations for further reading 216
- Subject index 219