

Table of contents

1	Piston rings	1
1.1	Purpose and function of piston rings	1
1.2	Functional principles	3
1.3	Forces and stresses	4
1.4	Types of piston rings	6
1.4.1	Rectangular ring	9
1.4.2	Rectangular ring with conical running surface	9
1.4.3	Piston ring with internal bevel or internal step (top)	9
1.4.4	Piston ring with internal bevel or internal step (bottom)	10
1.4.5	Keystone ring	10
1.4.6	First piston ring with barrel-shaped surface	11
1.4.7	Napier ring with conical running surface	11
1.4.8	Ring gap configuration	12
1.4.9	Slotted oil control ring	12
1.4.10	Spring-loaded oil control ring	13
	1.4.10.1 Oil control ring with coil spring	13
	1.4.10.2 Three-piece oil control ring (expander ring)	15
1.4.11	U-flex ring	15
1.5	Design details	16
1.5.1	Analysis and simulation	16
	1.5.1.1 Numerical analysis	16
	1.5.1.2 Stress analysis	16
	1.5.1.3 Dynamic analysis	16
	1.5.1.4 Ring conformability	17
	1.5.1.5 Specific contact pressure	17
	1.5.1.6 Ovality	17
	1.5.1.7 Design specifications	18
1.6	Materials, coatings, and surface treatment	18
1.6.1	Materials	18
	1.6.1.1 Cast iron	18
	1.6.1.2 Steel	19
1.6.2	Coatings and surface treatments	19
	1.6.2.1 Gray cast iron as a base material	20
	1.6.2.2 Martensitic nodular cast iron as a base material	21
	1.6.2.3 Carbon and stainless steels	21
	1.6.2.4 Running surface and side face coatings	22
	1.6.2.5 Nitriding running surfaces	23
	1.6.2.6 Surface protection	24

2	Piston pins and piston pin circlips	25
2.1	Function of the piston pin	25
2.2	Requirements	26
2.2.1	General	26
2.2.2	Strength	27
2.2.3	Deformation	28
2.2.4	Lubrication, oil supply	31
2.2.5	Wear	31
2.2.6	Weight	31
2.3	Types of piston pins	31
2.4	Design	33
2.4.1	Dimensioning	33
2.4.2	Analysis	35
2.4.3	Finite element analysis	36
2.4.4	Dimensional and form tolerances, standard	38
2.5	Materials	40
2.6	Coating	43
2.7	Component testing	44
2.8	Piston pin circlips	45
3	Bearings	47
3.1	Product range	47
3.1.1	Applications	47
3.1.2	Types and terminology	47
3.2	Design specifications	50
3.2.1	Properties	50
3.2.2	Load carrying capacity.....	50
3.2.3	Wear resistance	52
3.2.4	Stop-start applications	52
3.2.5	Seizure resistance	54
3.2.6	Embeddability	54
3.3	Bearing geometry	55
3.3.1	Bearing diameter and length	55
3.3.2	Grooves and bores	56
3.3.3	Bearing clearance	56
3.3.4	Fit of bearings and bushings	57
3.4	Numerical simulation	58
3.4.1	Hydrodynamic lubrication (mobility method)	58
3.4.2	Specialized simulations (TEHL)	60
3.4.3	Additional CFD simulations	61
3.4.4	Interference and assembly simulations	62
3.5	Materials	63
3.6	Market requirements and technology trends	67

4	Connecting rod	69
4.1	Introduction	69
4.2	Stresses	71
4.3	Requirements	72
4.4	Big end bore	73
4.4.1	Cracking (fracture splitting)	73
4.4.2	Angle split of the big end bore	74
4.5	Connecting rod shank	75
4.6	Small end bore	75
4.6.1	Pin bearing in the small end bore	75
4.6.2	Geometry of the connecting rod small end	76
4.6.3	Lubrication of the small end bore	77
4.6.4	Bushingless pin bearing in the small end bore	78
4.7	Guiding the connecting rod	79
4.8	FE analysis of the connecting rod	80
4.8.1	Modeling	80
4.8.2	Stresses from assembly	81
4.8.2.1	Bolt force	82
4.8.2.2	Bushings, bearings, and shrink fit	82
4.8.3	Stresses from engine operation	83
4.8.3.1	Gas force	84
4.8.3.2	Inertial force	85
4.9	Component testing of the connecting rod	88
4.10	Materials	92
4.10.1	Steels for forged connecting rods	92
4.10.2	Sinter-forged connecting rods	93
4.11	Connecting rod bolting	93
4.11.1	Requirements for connecting rod bolting	93
4.11.2	Design and analysis of connecting rod bolting	94
4.11.3	Shape of the connecting rod bolts	95
5	Crankcase and cylinder liners	97
5.1	Introduction	97
5.1.1	Forces and stresses	97
5.1.2	Development goals	98
5.2	Types of crankcases	98
5.2.1	Methods for attenuating noise emissions	99
5.2.2	Main bearing seats	100
5.2.3	Cooling	101
5.3	Crankcase materials	102
5.3.1	Cast iron	102
5.3.2	Aluminum alloys and material properties	102

5.3.2.1	Effects of the casting process on the material properties of aluminum alloys	106
5.3.2.2	Effects of heat treatment on the properties of cast aluminum alloys	107
5.3.3	Magnesium	108
5.3.4	Material trends	108
5.3.5	Effects of the casting process on the design of the crankcase	108
5.3.5.1	Sand casting	108
5.3.5.2	COSCAST™ process	109
5.3.5.3	Molding sand–“green sand”	109
5.3.5.4	CPS method	109
5.3.5.5	Full-mold casting method (lost foam method)	110
5.3.5.6	Permanent mold casting	110
5.3.5.7	Gravity die casting	110
5.3.5.8	Low-pressure die casting	110
5.3.5.9	High-pressure die casting	111
5.3.5.10	Squeeze casting	111
5.3.5.11	Semisolid process.....	111
5.4	Cylinder liners and cylinder surfaces	111
5.4.1	Requirements for the cylinder surface	111
5.4.2	Cylinder surfaces in aluminum crankcases	112
5.4.3	Types of cylinder liners	113
5.4.4	Materials	117
5.4.5	Surface treatment	120
5.5	Light-alloy cylinders	120
5.5.1	Types of light-alloy cylinders for small engines	121
5.5.2	Air-cooled cylinders	121
5.5.3	Port shapes and gas exchange in two-stroke engines	122
5.5.4	Cylinders for four-stroke engines	125
5.5.5	Surface treatment	125
Glossary		129
Keyword index		131