Contents

PERFACE ix

NOMENCLATURE. xi

CHAPTER 1. THERMO-HYDRODYNAMIC LUBRICATION 1

1.1. Global thermal balance 1
1.2. Energy equation for the lubricant film 4
1.2.1. Particular case of non-filled film zones 5
1.3. Fourier equation inside the solids 6
1.4. Boundary conditions 7
1.4.1. Supply ducts 7
1.4.2. External walls of solids 8
1.4.3. Surfaces at solid truncations 9
1.4.4. Interfaces between film and solids 9
1.4.5. Supply orifices and grooves 11
1.4.6. Axial extremities of the lubricant film 17
1.5. Bibliography 17

CHAPTER 2. THREE-DIMENSIONAL THERMO-HYDRODYNAMIC MODEL 19

2.1. Model description 19
2.2. Discretization of the film energy equation 20
2.2.1. Stationary case. 20
2.2.2. Transient case 27
2.3. Discretization of Fourier equation in the solids 38
2.4. Assembly of discretized equations for the film and the solids 40
2.5. Numerical behavior of the THD finite element model 43
2.5.1. Definition of reference problems. 43

2.5.2. Behavior for a stationary case 45
2.5.3. Behavior for a transient case 57
2.5.4. Behavior in the case of a variation in the axial direction of the film thickness 69
2.5.5. Evaluation of the global thermal method (GTM) 70
2.6. Bibliography 71

CHAPTER 3. SIMPLIFIED THERMO-HYDRODYNAMIC MODELS 73

3.1. Simplified THD model based on the Rhode and Li assumptions. 73
3.1.1. Expression of the pressure and reduced Reynolds equation 73
3.1.2. Velocity components 75
3.1.3. Energy and Fourier equations 76
3.1.4. Discretization of equations 77
3.1.5. Evaluation of the method based on Rhode and Li assumptions . . . 82
3.2. Simplified models for cyclic regimes. 85
3.2.1. Model with the temperature averaged on the film thickness (ATM) 87
3.2.2. Model with a parabolic temperature profile across the film thickness (PTM). 95
3.3. Bibliography 101

CHAPTER 4. COMPUTING THE THERMOELASTIC DEPENDENCY MATRICES 103

4.1. Computing the thermoelastic dependency matrices to be used for the three-dimensional and Rhode and Li models 104
4.2. Computing the thermoelastic dependency matrices to be used for the simplified models 105
4.2.1. Equation setting for compliance matrices when the thermal boundary layer is modeled by a transfer coefficient 106
4.2.2. Equation setting for compliance matrices when the thermal boundary layer is modeled by a Fourier series 107
4.3. Bibliography 110

CHAPTER 5. GENERAL ALGORITHM AND SOFTWARE FOR SOLVING BEARING LUBRICATION PROBLEMS 111

5.1. Parameters and equations 111
5.1.1. The parameters that must be known before computing 111
5.1.2. The unknown parameters, objective of the computation 113
5.1.3. The equations to be solved 114
5.2. General algorithm 115

5.3. Solving finite element discretized EHD problem
with the Newton–Raphson method 117
5.3.1. Constitutive equations for the EHD problem 117
5.3.2. Discretized equations for the EHD problem 119
5.3.3. Solving algorithm for the EHD problem 129
5.4. Techniques for reducing the computation time 131
5.4.1. Non-systematic evaluation of the Jacobian matrix 131
5.4.2. Decomposition of the hydrodynamic pressure 132
5.5. Mesh refinement 138
5.5.1. Principle of the refinement method 138
5.5.2. Computation of the local compliance matrix 140
5.5.3. Expression of the shell surface deformation 141
5.6. Architecture of software for bearing lubrication computation 143
5.7. An example of TEHD computation software: ACCEL 145
5.8. Bibliography 147

APPENDIX 149

INDEX 153