

Contents

1 Introduction	1
Yuntao Song, Weiyue Wu, Shijun Du and Xiaojun Ni	
1.1 Foreword	1
1.2 Main Components of Tokamak	3
1.2.1 Magnets	4
1.2.2 Vacuum Vessel	7
1.2.3 In-vessel Components	8
1.2.4 Cryostat	11
1.2.5 Feeder	12
1.2.6 Diagnostic	12
1.3 Review	13
1.4 Content	17
References	18
2 Mechanical Basics	21
Weiyue Wu, Yuntao Song, Shijun Du and Zhongwei Wang	
2.1 Mechanics in Tokamak	21
2.1.1 Material Mechanics	21
2.1.2 Elasticity Mechanics	26
2.1.3 Fluid Mechanics	33
2.1.4 Heat Transfer	37
2.1.5 Electromagnetics	40
2.2 Code and Standard	43
2.2.1 Introduction	43
2.2.2 American Nuclear Standard	43
2.2.3 French Nuclear Standard	44
2.2.4 Fusion Project Standard	44
References	45
3 Electromagnetic, Structural and Thermal Analyses of the Vacuum Vessel	47
Yuntao Song, Weiyue Wu, Weiwei Xu, Xufeng Liu and Sumei Liu	
3.1 Introduction	47
3.2 Analysis of the Eddy Current and the EM Force for VV	51

3.2.1	Analytical Analysis of the Eddy Current for VV During MD	51
3.2.2	3D FEM Analysis of the Eddy Current for VV During MD	61
3.2.3	Analytical Analysis of the Halo Current EM Force for VV During VDE.	69
3.3	Temperature Field and Thermal Stress Analysis of the VV.	71
3.3.1	Introduction	71
3.3.2	The Structures of the Baking Systems	71
3.3.3	The Heat Balance Equations.	73
3.3.4	The Temperature Field Equations and Boundary Conditions.	77
3.3.5	The Temperature Field Analysis of VV	78
3.3.6	The Thermal Stress Analysis of VV	81
3.3.7	Structural Analysis of VV in the Case of Load Combination.	82
3.4	Dynamic Mechanical Analyses	85
3.4.1	Basic Mode Deformation	85
3.4.2	Analysis of Dynamic EM Force	86
3.4.3	Seismic Analysis.	87
3.5	Buckling Analysis for the VV.	89
3.6	Analysis of Fatigue Life for VV	91
3.7	Analysis of the Neutron Shielding Blocks of VV	92
3.7.1	Design Description of the Neutron Shielding Blocks.	92
3.7.2	EM Analysis of the Neutron Shielding Blocks	93
3.7.3	Thermal-Structural Analysis of the Neutron Shielding Blocks.	94
3.8	Summary	96
	References	97
4	In-vessel Components.	99
	Yuntao Song, Mingzhun Lei, Xuebing Peng, Weiwei Xu, Weiyue Wu and Shijun Du	
4.1	Introduction	99
4.1.1	Functions of the In-vessel Components	100
4.1.2	Design Requirements and Operation Loads for the In-vessel Components	102
4.1.3	Overall Structure of the In-vessel Components	104
4.2	Electromagnetic and Structural Analyses of Plasma Facing Components	105
4.2.1	Electromagnetic Analysis of the Passive Stabilizers	105
4.2.2	Electromagnetic Analysis of the Divertor.	113
4.2.3	Electromagnetic and Structural Analyses of VV and Plasma Facing Components	117
4.3	Thermal and Mechanical Analysis of Divertor	122

4.3.1	Function of Divertor	122
4.3.2	Selection of Structural Materials and Technology of Heat Removal.	124
4.3.3	Divertor Shape and Structure	128
4.3.4	Thermo-mechanical Behavior of Divertor	134
4.3.5	Accurate Thermal and Mechanical Analysis by FEM: Example of EAST Divertor	139
4.4	Blanket.	146
4.4.1	Functions	146
4.4.2	Basic Structure Description	147
4.4.3	Hydraulic and Thermo-mechanical Analyses of the Shield Block	149
	References	156
5	Superconducting Magnet	159
	Shijun Du, Weiyue Wu, Yuntao Song, Xufeng Liu and Jinxing Zheng	
5.1	Introduction	159
5.2	Cable-In-Conduit-Conductor (CICC)	160
5.2.1	Composite Material of CICC	161
5.2.2	Macro-research Overview About the Effective Elastic Properties of the Composite Material	163
5.2.3	Even Theory and Its Analysis Process	164
5.2.4	The Finite Element Numerical Methods for Analysis of Equivalent Elastic Properties of Composite Materials	170
5.2.5	Calculation Results and Analysis	173
5.2.6	Damage of Composite Material	173
5.3	Mechanical Design Criteria of the Superconducting Magnet System	175
5.3.1	The General Structure of Superconducting Magnet System of Tokamak Device	176
5.3.2	The Forces and Design Criteria of the Superconducting Magnet System	176
5.4	Mechanical Analysis of the Superconducting Magnet System	182
5.4.1	Electromagnetic Force Analysis of the Superconducting Magnet	182
5.4.2	The Mechanical Properties of the Magnet System in the Cooldown Process	194
5.4.3	Mechanical Analysis of the Insulation Structure in Magnet System	195
5.5	The Mechanical Analysis on the Welding of the Magnet System	198
5.6	Summary	199
	References	200

6 Thermal Shield 203

Mingzhun Lei, Yuntao Song, Sumei Liu and Shijun Du

6.1 Thermal Shield System Description 203

6.1.1 System Functions 203

6.1.2 Thermal Shield Structure 204

6.2 Theoretical Analysis 207

6.3 The Calculation of the Electromagnetic Effects, Eddy Current
Losses, and Electromagnetic Force 212

6.3.1 Simplified Model for Simulation. 213

6.3.2 Equivalent Time Constant of the Thermal Shield
and its Influence for Vertical Field Penetration. 214

6.3.3 Eddy Current Loss and Electromagnetic Force
of the Thermal Shield 218

6.4 Conclusion 221

References 222

7 Cryostat 223

Weiyue Wu, Yuntao Song, Shijun Du, Songke Wang and Xiaojun Ni

7.1 Introduction 223

7.2 General Description 224

7.2.1 Overview 224

7.2.2 Cryostat Operation and Loading Conditions 227

7.3 Structure Analysis of Cryostat. 229

7.3.1 Structural Analysis 230

7.3.2 Buckling Analysis. 232

7.4 Seismic Analysis of Cryostat 233

7.4.1 General Description of Seismic Event 233

7.4.2 General Seismic Analysis Methods 234

7.4.3 Seismic Analysis of EAST Cryostat by FEM 238

7.5 Summary 240

References 241