

Proceedings of the 19th International Ship and Offshore Structures Congress

Editors

C. Guedes Soares & Y. Garbatov

*Centre for Marine Technology and Ocean Engineering (CENTEC), Instituto
Superior Técnico, Universidade de Lisboa, Lisbon, Portugal*

VOLUME 1



CRC Press

Taylor & Francis Group

Boca Raton London New York Leiden

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

A BALKEMA BOOK

CRC Press/Balkema is an imprint of the Taylor & Francis Group, an informa business

© 2015 Taylor & Francis Group, London, UK

Typeset by MPS Limited, Chennai, India

Printed and bound in Great Britain by CPI Group (UK) Ltd, Croydon, CR0 4YY

All rights reserved. No part of this publication or the information contained herein may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, by photocopying, recording or otherwise, without written prior permission from the publishers.

Although all care is taken to ensure integrity and the quality of this publication and the information herein, no responsibility is assumed by the publishers nor the author for any damage to the property or persons as a result of operation or use of this publication and/or the information contained herein.

Published by: CRC Press/Balkema
P.O. Box 11320, 2301 EH Leiden, The Netherlands
e-mail: Pub.NL@taylorandfrancis.com
www.crcpress.com – www.taylorandfrancis.com

ISBN set: 978-1-138-02895-1 (2 volumes hardback and CDROM)

ISBN Volume 1: 978-1-138-02896-8

ISBN Volume 2: 978-1-138-02897-5

ISBN: 978-1-315-64719-7 (eBook PDF)

Table of contents

Preface

xxv

VOLUME 1

Report of Committee I.1: Environment

1

1	Introduction	4
2	Environmental data	5
2.1	Wind	6
2.1.1	Locally sensed wind measurements	6
2.1.2	Remotely sensed wind measurements	7
2.1.3	Numerical modelling to complement measured data	8
2.2	Waves	8
2.2.1	Locally sensed wave measurements	9
2.2.2	Remotely sensed wave measurements	12
2.2.3	Numerical modelling to complement measured data	13
2.2.4	Wave description from measured ship motions	14
2.3	Current	14
2.3.1	In-situ current measurements	14
2.3.2	Remotely sensed current measurements	15
2.3.3	Numerical modelling to complement measured data	15
2.4	Sea water level	15
2.4.1	Locally sensed sea water level measurements	15
2.4.2	Remotely sensed sea water level measurements	15
2.4.3	Numerical modelling to complement measured data	15
2.5	Ice and snow	15
2.5.1	Locally and remotely sensed ice and snow measurements	15
2.5.2	Numerical modelling to complement measured data	16
3	Environmental models	17
3.1	Wind	17
3.1.1	Analytical description of wind	18
3.1.2	Statistical and spectral description of wind	18
3.2	Waves	20
3.2.1	Analytical and numerical wave models	20
3.2.2	Experimental description of waves	28
3.2.3	Statistical description of waves	30
3.2.4	Spectral description of waves	32
3.3	Current	33
3.3.1	Analytical description of current	33
3.3.2	Statistical and spectral description of current	34
3.4	Sea water level	34
3.5	Ice and snow	34
4	Climate change	34
4.1	New IPCC scenarios and climate models	35
4.1.1	Temperature	36
4.1.2	Ice and snow	37
4.1.3	Sea water level	38

4.1.4	Wind and waves	38
4.1.5	Ocean circulation	40
5	Special topics	40
5.1	Hurricane	40
5.2	Wave current interaction	41
5.2.1	Wave-current interaction model	41
5.2.2	Numerical and analytical method	43
5.2.3	Experiments and measurements	44
5.3	Wave and wind energy resource assessment	45
6	Design and operational environment	47
6.1	Design	47
6.1.1	Met-Ocean data	47
6.1.2	Design environment	48
6.1.3	Design for climate change and rogue waves	51
6.2	Operations	52
6.2.1	Planning and executing marine operations	53
6.2.2	Northern sea route, weather routing, warning criteria and current	54
6.2.3	Eco-efficiency ship operation	56
7	Conclusions	57
7.1	Advances	59
7.2	Recommendations	60
	Acknowledgements	60
	References	61
	Report of Committee I.2: Loads	73
1	Introduction	75
2	Computation of wave-induced loads	75
2.1	Zero speed case	75
2.1.1	Body – wave interactions	75
2.1.2	Body-wave-current interactions	79
2.1.3	Multibody interactions	79
2.2	Forward speed case	80
2.3	Hydroelasticity methods	83
2.4	Loads from abnormal waves	85
3	Ship structures – specialist topics	87
3.1	Slamming and whipping	87
3.2	Sloshing	91
3.2.1	Analytical methods	91
3.2.2	Experimental investigations	92
3.2.3	Numerical simulation	93
3.2.4	Sloshing with internal suppressing structures	94
3.2.5	Sloshing and ship motions	95
3.3	Green water	96
3.4	Experimental and full scale measurements	99
3.5	Loads due to damage following collision/grounding	101
3.6	Weather routing and operational guidance	102
4	Offshore structures specialist topics	104
4.1	Vortex-induced vibrations (VIV) and vortex-induced motions (VIM)	104
4.1.1	VIV	104
4.1.2	VIM	106
4.2	Mooring systems	108
4.3	Lifting operations	111

4.4	Wave-in-deck loads	113
4.5	Floating offshore wind turbines	113
5	Probabilistic modelling of loads on ships	115
5.1	Probabilistic methods	115
5.2	Equivalent design waves	117
5.3	Design load cases and ultimate strength	119
6	Fatigue loads for ships	120
7	Uncertainty analysis	123
7.1	Load uncertainties	123
7.2	Uncertainties in loading conditions	124
8	Conclusions	125
	References	128

Report of Committee II.1: Quasi-static response

141

1	Introduction	144
2	Strength assessment approaches	144
2.1	Modelling of loads by quasi-static analysis	144
2.2	Response calculation	146
2.3	Reliability	147
3	Calculation procedures	148
3.1	Taxonomy of engineering assessment methods	148
3.1.1	Simplified analysis (rule-based design) / first principles	148
3.1.2	Direct calculations	148
3.1.3	Reliability analyses	148
3.1.4	Optimisation-based analyses	149
3.2	Design for production loads modelling	149
3.2.1	Rules versus rational based ship design	149
3.2.2	Direct simulations for global quasi-strength assessment	149
3.2.3	Loads extracted from experiments and testing	151
3.2.4	Loads from seakeeping codes	152
3.3	Structural modelling	152
3.3.1	Finite element modelling	152
3.3.2	Models for global and detailed analyses	152
3.3.3	Composite structures	153
3.4	Structural response assessment	153
3.4.1	Buckling and ultimate strength	153
3.4.2	Fatigue strength	154
3.4.3	Ship dynamics – vibrations	155
3.5	Validation of calculation results	155
3.5.1	Model scale experiments and testing	156
3.5.2	Full scale hull stress monitoring	160
4	Uncertainties associated with reliability-based quasi-static response assessment	161
4.1	Uncertainties associated with loads	161
4.1.1	Still water and wave loads	161
4.1.2	Ice loads	162
4.1.3	Combination factors	162
4.2	Uncertainties in structural modelling	163
4.2.1	Corrosion	163
4.2.2	Structural characteristics	164
4.2.3	Reliability and risk-based structural assessment	165
4.2.4	Methods and criteria	165
4.2.5	Structural capacity	166

4.3	Risk-based inspection, maintenance and repair	167
4.3.1	Inspection	167
4.3.2	Maintenance and repair	168
5	Ship structures	169
5.1	Developments in international rules and regulations	169
5.1.1	IMO goal-based standards	169
5.1.2	IACS common structural rules for bulk carriers and oil tankers	170
5.1.3	Development of structural design software systems	172
5.2	Special ship concepts	173
5.2.1	Service vessels for wind mills and offshore platforms	173
5.2.2	Container ships	173
5.2.3	LNG/LPG tankers	174
5.2.4	Other ship types	175
6	Offshore structures	176
6.1	Types of analysis for various floating offshore structures	176
6.2	Types of analysis for various fixed offshore structures	179
6.3	Uncertainty, risk and reliability in offshore structural analysis	182
7	Benchmark study	184
7.1	Methodology	184
7.2	Simplified methods	186
7.3	Quasi-static linear FE analysis	188
7.4	Nonlinear, transient dynamic FE analysis	188
7.5	Concluding remarks	190
8	Conclusions and recommendations	191
	References	192

Report of Committee II.2: Dynamic response **209**

1	Introduction	211
2	Ship structures	211
2.1	Environmental-induced vibrations	211
2.1.1	Wave-induced vibration	211
2.1.2	Ice-induced vibration	219
2.2	Machinery or propeller-induced vibrations	220
2.2.1	Propeller-induced vibration	220
2.2.2	Machinery-induced vibration	220
2.2.3	Numerical and analytical vibration studies of ship structures	221
2.3	Noise	222
2.3.1	Interior noise	222
2.3.2	Air radiated noise	224
2.3.3	Underwater radiated noise	224
2.4	Sloshing impact	227
2.4.1	Experimental approaches	227
2.4.2	Numerical modelling	228
2.4.3	CCS structural response	229
2.4.4	Current approaches for sloshing assessment	229
2.5	Air blast and underwater explosion	229
2.5.1	Air blast	229
2.5.2	Underwater explosion	230
2.6	Damping and countermeasures	232
2.7	Monitoring	234
2.7.1	Hull structural monitoring system	234

2.7.2	New sensors technology and application	234
2.7.3	New full scale monitoring campaigns and related studies	236
2.8	Uncertainties	239
2.9	Standards and acceptance criteria	241
2.9.1	Habitability	241
2.9.2	Underwater noise	242
2.9.3	Others	242
3	Offshore structures	243
3.1	Vibration	243
3.1.1	Wind-induced vibration	243
3.1.2	Wave-induced vibration	244
3.1.3	Vortex-induced motion	245
3.1.4	Internal flow-induced vibration	246
3.1.5	Ice-induced vibration	246
3.2	Very large floating structures	249
3.3	Noise	249
3.3.1	Analysis of underwater noise by pile-driving	250
3.3.2	Measurement and mitigation of underwater noise	250
3.3.3	Equipment noise	250
3.4	Blast	251
3.5	Damping and countermeasures	252
3.6	Uncertainties	253
3.7	Standards and acceptance criteria	254
4	Conclusion	254
	References	257
	Report of Committee III.1: Ultimate strength	279
1	Introduction	282
2	Fundamentals	283
2.1	Design for ultimate strength	283
2.2	General characteristics of ultimate strength	283
3	Assessment procedure for ultimate strength	284
3.1	Empirical and analytical methods	284
3.1.1	Introduction	284
3.1.2	Hull structures	285
3.1.3	Residual strength of damage hull structures	286
3.1.4	Plates and stiffened plates	288
3.2	Numerical methods	288
3.2.1	Introduction	288
3.2.2	Nonlinear FE method	289
3.2.3	Idealized structural unit method	290
3.2.4	Conclusion	290
3.3	Experimental methods	291
3.4	Reliability assessment	292
3.5	Rules and regulations	294
3.5.1	Harmonized common structural rules	294
3.5.2	Updates to offshore rules and guides	298
4	Ultimate strength of various structures	299
4.1	Tubular members and joints	299
4.1.1	Tubular members	299
4.1.2	Tubular joints	300

4.2	Steel plate and stiffened plates	301
4.2.1	Introduction	301
4.2.2	Analytical formulations for ultimate strength of stiffened panels	302
4.2.3	Uniaxial compression	302
4.2.4	Multiple load effects	303
4.2.5	Panels with openings, cut-outs or rupture damage	304
4.2.6	Welding effects	304
4.2.7	In service degradation	305
4.2.8	Experimental testing	305
4.2.9	Optimization	306
4.2.10	Conclusions	306
4.3	Shells	306
4.4	Ship structures	308
4.4.1	Progressive collapse methods	309
4.4.2	Damaged structures	310
4.4.3	Corrosion	310
4.4.4	Complex ship structural components and complex loading	310
4.4.5	Reviews and applications	312
4.5	Offshore structures	312
4.6	Composite structures	314
4.6.1	Failure identification and material degradation models	315
4.6.2	Ultimate strength of composite stiffened panels and box girders	316
4.6.3	Environmental effects	317
4.6.4	Compression after impact	317
4.7	Aluminum structures	318
4.7.1	Introduction	318
4.7.2	Weld-induced effects	318
4.7.3	Formulation development	320
4.7.4	Experimental investigation	320
4.7.5	Fiber-reinforced polymer strengthened	321
4.7.6	Sandwich panels	321
4.7.7	Hull girder	321
4.7.8	Summary and recommendation for future works	322
5	Benchmark study	322
5.1	Small box girder	322
5.1.1	Introduction	322
5.1.2	Model parameters	323
5.1.3	Baseline calculations	324
5.1.4	Comparison with solid element mesh	327
5.1.5	Comparison with Smith method	328
5.1.6	Effect of imperfection amplitude and shape	329
5.1.7	Effect of material model parameters	331
5.1.8	Effect of plating thickness	331
5.1.9	Summary/conclusions	332
5.2	Three hold model of hull girder	332
5.2.1	Calculation cases	332
5.2.2	Calculation results	335
5.3	Summary and recommendation for future works	338
6	Conclusion and recommendation	339
	References	340

Report of Committee III.2: Fatigue and fracture		351
1	Introduction	354
2	Fatigue life-cycle design philosophies and methodologies	354
2.1	Fatigue and fracture in marine structures	354
2.2	Preliminary design	354
2.3	Detailed design	354
2.4	Fabrication	355
2.5	In-service maintenance	355
2.5.1	Inspection techniques	355
2.5.2	Inspection planning	355
2.6	Fatigue strength	355
2.6.1	S-N curves related to expected workmanship	355
2.6.2	Crack propagation parameters	355
2.7	Fracture strength	356
2.8	Fatigue loads	356
2.8.1	Wave loads	356
2.8.2	Loading unloading	356
2.8.3	Vibrations	356
2.9	Environmental effects	356
2.9.1	In air	357
2.9.2	Seawater	357
2.9.3	Other aggressive environments	357
2.9.4	Coating and coating life	357
2.10	Fatigue, fracture & failure criteria	357
2.10.1	Failure definition	357
2.10.2	Uncertainties	357
2.10.3	Safety factors	358
3	Factors influencing fatigue/fracture	358
3.1	Resistance	358
3.1.1	Thickness and size	358
3.1.2	Environment (corrosion)	359
3.1.3	Temperature	362
3.1.4	Residual stress & constraint, mean stress	363
3.2	Materials	364
3.2.1	Metallic alloys	364
3.2.2	Fatigue & fracture improvements through material changes, surface treatment	364
3.3	Loading	365
3.3.1	Stochastic loading (load interaction effects (sequence))	365
3.3.2	Cycle counting – spectral, time-domain, stress ranges, means stress effect	365
3.3.3	Complex stresses	366
3.3.4	Recent developments in multiaxial fatigue criteria	369
3.4	Structural integrity/life cycle management	373
3.4.1	Fabrication and repair	373
3.4.2	Inspection & monitoring of structure and coatings	374
3.4.3	Inspection and maintenance	376
3.5	Composites	377
4	Fatigue assessment methods	378
4.1	Overview	379
4.2	Fatigue damage models	381
4.2.1	Stress based concepts	381

4.2.2	Strain concepts	382
4.2.3	Notch-intensity factor, -integral and -energy density concepts	382
4.2.4	Confidence and reliability	383
4.3	Fracture mechanics models	385
4.3.1	Crack growth rate model	389
4.3.2	Crack growth assessment	390
4.3.3	Fracture mechanics based fatigue evaluation of ship structures	391
4.4	Rules, standards & guidance	392
4.4.1	Ship rules	392
4.4.2	Design codes for offshore structures	394
4.4.3	IIW recommendation	395
4.4.4	ISO standards	395
4.5	Acceptance criteria	395
4.6	Measurement techniques	396
4.6.1	Crack growth and propagation	396
4.6.2	Fatigue	397
4.6.3	Material properties	398
4.6.4	Fracture toughness	398
5	Benchmarking study	399
5.1	Problem statement	399
5.2	Analytical methods	400
5.3	Numerical analysis using FEM	402
5.4	Results	403
5.5	Discussion & benchmarking study conclusions	404
6	Summary & conclusions	404
	References	405
	Report of Committee IV.1: Design principles and criteria	415
1	Introduction	418
1.1	General concept of sustainability oriented design	418
1.2	Goal oriented normative framework	418
1.3	Procedures for the impact analysis of regulations	419
2	Quantification of sustainability aspects	419
2.1	Economic aspects	419
2.2	Human aspects	420
2.3	GCAF and NCAF indicators for loss of life	420
2.3.1	Life Quality Index	421
2.3.2	DALY and QALY indicators	422
2.4	Environmental aspects	423
2.4.1	Cost of averting a tonne of oil spilt (CATS)	423
2.4.2	CO ₂ emissions costs	427
2.4.3	Other emissions costs	428
3	Depreciation rates in decision making	430
3.1	Pure time preferences	431
3.2	Precautionary approach vs standard economic theory	431
3.3	Integrated Assessment Models	432
3.4	Tails of the probability distributions	434
3.5	Role of the discounting rate	434
3.6	Conclusion (depreciation rates)	437
4	Examples related to sustainability oriented design	437
4.1	Probability based design	437

4.2	Lifecycle design	439
4.3	Lifecycle design considering future climate change	441
5	Regulatory framework for marine structures	443
5.1	Development of goal based standards at IMO	444
5.1.1	IACS harmonized common structural rules for bulk carriers and tankers	444
5.1.2	Goal based standards/safety level approach (GBS/SLA) at IMO	446
5.2	Regulatory actions implemented at IMO targeting environmental protection	447
5.2.1	Energy Efficiency Design Index (EEDI)	447
5.2.2	NO _x SO _x control	447
5.2.3	Emission control areas	447
5.2.4	MARPOL Annex V prevention of pollution by garbage from ships	448
5.2.5	IMO ship recycling (the Hong Kong convention)	448
5.2.6	Pre-normative investigations at imo in the field of noise radiation into water	449
5.3	Other (non IMO) regulatory actions in the field of ships	449
5.3.1	Developments in the naval ship code	449
5.3.2	Inland vessels	450
5.3.3	EU directive on safety of offshore oil and gas operations	451
5.4	Comments on the recent developments in the normative framework	451
6	Studies focussing on environmental impact	451
6.1	Studies on green house gas emissions	451
6.2	Studies on countermeasures to limit emissions	452
6.2.1	Slow steaming	452
6.2.2	Scale effects and propulsive improvements	452
6.2.3	Discussions of the EEDI concept	452
6.2.4	Studies on control of NO _x and SO _x emissions	453
6.2.5	Emissions trading schemes	453
6.2.6	Alternative fuels	453
7	Conclusions	453
	References	454
Report of Committee IV.2: Design methods		459
1	Introduction	461
2	Design methodology	461
2.1	Developments in procedural aspects of ship design methodology	462
2.2	Developments in “Design-for-X” and risk-based design	462
2.3	Developments in ship form-function mapping, tradespace searches	465
2.4	Handling uncertainty in future operating context	466
3	Design tools	467
3.1	Introduction	467
3.2	Development of design tools	467
3.3	Tools for lifecycle cost modeling and lifecycle assessment	469
3.4	Links between design tools and production and operational phases	469
3.5	Developments in integrated naval architecture packages	471
4	Optimization developments	472
4.1	Introduction to Design Support Systems (DESS)	472
4.2	Parallel processing and hardware developments	475
4.3	Developments in structural optimization algorithms (optimization solvers– Σ)	477
4.4	Surrogate modeling and variable fidelity approaches (surrogate solvers– Ξ)	482
4.4.1	Surrogate modeling in design and optimization	483
4.4.2	Surrogate modeling in risk and safety analyses	484

4.5	Optimization for production (design quality modules– $\Omega^{\text{PRODUCTION}}$)	484
4.6	Optimization for lifecycle costing (design quality modules– Ω^{LCC})	486
5	Classification society software review	487
5.1	Background, motivation, and aim	487
5.2	Tool analysis	488
5.2.1	Overall functionality	488
5.2.2	Evaluation criteria	488
5.3	Classification societies tools details	490
5.3.1	American Bureau of Shipping (ABS)–www.eagle.org	490
5.3.2	Bureau Veritas (BV)–www.bureauveritas.com	491
5.3.3	China Classification Society (CCS)–www.ccs.org.cn	491
5.3.4	Croatian Register of Shipping (CRS)–www.crs.hr	492
5.3.5	DNV–GL	493
5.3.6	Korean Register of Shipping (KR)–www.krs.co.kr	495
5.3.7	Nippon Kaiji Kyokai (ClassNK)–www.classnk.com	496
5.3.8	Polish Register of Shipping (PRS)–www.prs.pl	497
5.3.9	Registro Italiano Navale (RINA)–www.rina.org	498
5.4	Conclusions and future challenges	498
6	Structural lifecycle management	499
6.1	Introduction	499
6.2	Tool development	500
6.3	Data interchange and standards	502
6.4	Integration with repair	503
6.5	Integration with structural health monitoring systems	504
6.6	Summary of the lifecycle structural management systems	506
7	Obstacles, challenges, and future developments	506
8	Conclusion	508
	Acknowledgments	509
	References	509

VOLUME 2

	Report of Committee V.1: Accidental limit states	519
1	Introduction	523
2	Fundamentals of ALS design	524
2.1	Introduction	524
2.2	Codes and standards	525
2.3	Updates of codes and standards	527
2.4	Uncertainties in ALS in design	527
2.5	Practice for ships	527
3	Hazard identification	528
3.1	Introduction	528
3.2	Hazard identification	530
4	Safety levels in ALS design	532
4.1	Introduction	532
4.2	Safety level of offshore structures in ALS	532
4.2.1	General	532
4.2.2	Discussion of new ISO standards for offshore structures	532
4.2.3	Characterization of hazards	533
4.2.4	Accidental design situations	533
4.2.5	ALS safety levels implied in structural codes	533

4.3	Safety level of ship structures in ALS	535
4.3.1	General	535
4.3.2	GBS of ship structure design	535
4.3.3	Safety level in ULS in CSR	536
4.3.4	Safety level in ALS in CSR-H	536
5	Assessment of accidental loads	538
5.1	Introduction	538
5.2	Explosion load assessment	538
5.2.1	Deterministic approach	539
5.2.2	Probabilistic approach	539
5.2.3	Definition of explosion loads for design	542
5.3	Fire load assessment	542
5.3.1	Deterministic approach	542
5.3.2	Risk-based and probabilistic approach	543
5.4	Load assessment for collision accidents	544
5.4.1	Deterministic approach	545
5.4.2	Risk-based and probabilistic approach	545
5.5	Load assessment for dropped object accidents	546
5.5.1	Deterministic approach	546
5.5.2	Risk-based approach	547
6	Determination of action effects	547
6.1	Introduction	547
6.2	Review of numerical tools	549
6.3	Modelling geometries	550
6.4	Modelling loads	552
6.4.1	Ship collision	552
6.4.2	Dropped objects	553
6.4.3	Explosions	553
6.4.4	Fire	554
6.5	Material models	554
6.5.1	Plasticity model	557
6.5.2	Stress-strain curve	557
6.5.3	Failure criteria	557
6.6	Uncertainties of ALS models	560
6.7	Probabilistic methods	560
6.8	Appendix A	560
6.8.1	True stress-strain curve for Ls-Dyna	560
7	Benchmark study. Resistance of topside structures Subjected to fire	561
7.1	Scope of work	561
7.2	Strategy of benchmark study	562
7.3	Input	562
7.3.1	Geometry of target structure	562
7.3.2	Material data	563
7.3.3	Boundary conditions	564
7.3.4	Loads	564
7.4	Results	566
7.4.1	Static analysis	566
7.4.2	Push-down analysis	567
7.4.3	Fire analysis	568
7.4.4	Design of PFP	570
7.4.5	Effects of boundary conditions	571

7.4.6	Methods of controlling numerical instability for beam element model	571
7.4.7	Effects of local heat flux	573
7.5	Conclusion from the benchmark study	575
8	References	576
9	Annex 1. Material models for non-linear finite element analysis	579
9.1	Introduction	579
9.2	Guidelines and standards	580
9.3	Material model database	580
9.3.1	Steel	580
9.3.2	Aluminium	583
9.3.3	Foam, isolator, rubber	584
9.3.4	Ice	584
9.3.5	Air	585
9.3.6	Water	586
9.3.7	Explosives	586
9.3.8	Risers, umbilical or power cable	587
9.3.9	Composites	587
9.3.10	Concrete	588
9.3.11	Soil	588
9.4	References	589
Report of Committee V.2: Natural gas storage and transportation		591
1	Introduction	593
2	Background	593
3	Safety and design	595
3.1	Cargo containment	595
3.1.1	Non-self supporting tanks–membrane tanks	595
3.1.2	Independent tanks	595
3.1.3	New development of CCS	596
3.2	Structural integrity and rules	596
3.3	Sloshing	598
3.3.1	Global flow and sloshing-ship motion coupling, online sloshing prediction	598
3.3.2	Long-term assessment	599
3.3.3	Experimental methods, benchmark	600
3.3.4	Sloshing model test benchmark	600
3.3.5	Sloshing physics, scaling ELPs, dominating physics and relevant scaling laws	600
3.3.6	Numerical methods	601
3.4	Leakage	602
3.5	Fatigue	602
3.6	Collision, grounding, flooding	603
3.7	Sloshing control	605
3.8	Fire safety, temperature control of hull structures	605
4	LNG as fuel	608
4.1	Why LNG as fuel	608
4.2	LNG supply chain	608
5	Safety and design special applications	610
5.1	Floating LNG, FLNG, FSRU	610
5.2	Side by side or tandem mooring?	611
5.3	Arctic	612

6	Conclusions	612
	References	612
	Report of Committee V.3: Materials and fabrication technology	619
1	Introduction	622
2	General trends	622
2.1	Developments in the maritime markets and their impact on the trends in Fabrication and materials technologies	622
2.1.1	Korea	624
2.1.2	Japan	624
2.1.3	China	624
2.1.4	Europe	624
2.1.5	Brazil	625
2.2	Ongoing research programmes on fabrication and materials	625
2.2.1	Korea	625
2.2.2	Japan	626
2.2.3	China	626
2.2.4	Europe	626
2.2.5	Brazil	627
2.2.6	USA	628
3	Structural materials	629
3.1	Metallic materials	629
3.1.1	Aluminium alloys	629
3.1.2	Titanium	630
3.1.3	Metal foam	630
3.1.4	Application of metals in low temperatures	631
3.2	Non-metallic materials	633
3.2.1	Fire resistant materials	634
3.2.2	Bio-composites	634
3.2.3	Influence of sea water on non-metallic materials	636
3.2.4	Recycling and disposal	636
3.2.5	Application of non metallic materials at low temperatures	637
3.3	Hybrid materials	637
4	Joining and fabrication technology	637
4.1	Advances in joining technology	637
4.1.1	Welding automation and recent developments in joining technologies	637
4.1.2	Underwater welding	638
4.1.3	Frictions stir welding of steel	638
4.2	Innovations in fabrication technology	640
4.2.1	Plate bending with line heating	640
4.2.2	Post-treatment of welded joints and plate edges	640
4.2.3	Hybrid structures and joints	641
4.3	Influence of production quality on strength	642
4.3.1	Weld geometry and misalignments	642
4.3.2	Effect residual stress and distortions	643
4.3.3	Utilisation of high strength steel and thin plates	643
4.4	Dimension and quality control	644
5	Corrosion protection	644
5.1	Protection rules	644
5.2	Coating and paints	645
5.2.1	Epoxy-based coating systems	645

5.2.2	Zinc-rich paints	645
5.2.3	Thermal spraying and deposition	645
5.2.4	Antifouling (AF) coatings	646
5.2.5	Self healing coatings	646
5.2.6	Intelligent coatings	646
5.2.7	Ice-breaker coatings	646
5.3	Cathodic protection	647
5.4	Corrosion resistant steels	647
5.5	Corrosion monitoring	648
5.6	Non destructive testing	648
5.6.1	Visual inspection of welds	648
5.6.2	Inspection for delayed (hydrogen induced) cracking	648
5.6.3	Methods of inspection	649
5.6.4	Under film corrosion detection	649
6	Manufacturing simulation	649
6.1	Discrete event simulation and production optimization	650
6.1.1	Layout planning	650
6.1.2	Production planning	651
6.1.3	Outfitting and customization	651
6.1.4	Logistic simulations	652
6.2	Virtual and augmented reality	652
7	Welding simulation	653
7.1	Computation welding mechanics	653
7.2	Arc welding simulation methodologies	653
7.2.1	Sequentially coupled thermo-mechanical models	653
7.2.2	Thermo-mechanical staggered coupled	653
7.3	Heat source models	654
7.4	Material models	655
7.5	Thermal- and mechanical boundary conditions	656
7.6	Mesh size	657
7.7	Computational time and cost	657
7.8	Weld residual stress measurements	657
7.9	Benchmark case	658
8	Conclusions and recommendations	659
	References	660

Report of Committee V.4: Offshore renewable energy		669
1	Introduction	671
2	Offshore renewable energy resources	671
2.1	Offshore wind energy resources	671
2.1.1	Resource assessment	672
2.2	Wave energy resources	673
2.3	Tidal and ocean current energy resources	674
2.3.1	Physical resource assessment	674
2.3.2	Numerical resource modelling	674
3	Offshore wind turbines	675
3.1	Recent industry and research development	675
3.2	Numerical modelling and analysis	678
3.2.1	Numerical tools – state-of-the-art	678
3.2.2	Load and response analysis of bottom-fixed wind turbines	679
3.2.3	Load and response analysis of floating wind turbines	681

3.3	Physical testing	687
3.3.1	Laboratory testing	687
3.3.2	Field testing	689
3.4	Transportation, installation, operation and maintenance	689
3.4.1	Current industry and research development	690
3.4.2	Numerical simulations of marine operations	691
3.4.3	Guidelines on marine operations for offshore wind turbine transportation, installation, operation and maintenance	692
3.5	Rules and standards	692
4	Wave energy converters	693
4.1	Numerical modelling and analysis	695
4.1.1	Load and motion response analysis	695
4.1.2	Mooring analysis	698
4.1.3	Power take-off analysis	699
4.2	Physical testing	700
4.2.1	Laboratory testing and validation of numerical tools	701
4.2.2	Field testing	701
4.3	Rules and standards	702
5	Tidal and ocean current turbines	703
5.1	Development, modelling and testing of tidal current energy converters	703
5.1.1	Device development	703
5.1.2	Numerical modelling and experimental testing	703
5.2	Environmental impact	704
5.2.1	Marine planning	704
5.3	Economic feasibility	704
6	Combined use of ocean space	705
7	Conclusions and recommendations for future work	707
	References	709
	Report of Committee V.5: Naval vessel design	723
1	Introduction	726
2	Naval class rule development/progress	726
2.1	Introduction	726
2.2	Military structural requirements	727
2.3	Military operational safety loads	728
2.4	Military performance loads	729
2.5	Concluding remarks	729
3	Military loads	730
3.1	Underwater weapon effects	730
3.1.1	Primary shock wave	730
3.1.2	Shock wave reflections and cavitation	730
3.1.3	Bubble dynamics and jetting	731
3.1.4	Numerical modelling	731
3.2	Above water weapons effects	731
3.2.1	External blast	732
3.2.2	Internal blast	732
3.2.3	Bullets and fragments	733
3.3	Maritime improvised explosive devices	733
3.4	Concluding remarks	733
4	Naval service life management	733
4.1	Introduction	733

4.2	Ship service life in context	734
4.2.1	Australian LPA class	734
4.2.2	Australian Adelaide class FFG-07	734
4.2.3	ANZAC class	735
4.3	Determining the remaining life of a warship	735
4.4	Naval structural monitoring programs	737
4.5	Consequence of increasing displacement	738
4.6	Options for enhancing fatigue life of warships	738
5	Naval specific structure design	739
5.1	Structural uniqueness of naval ships	739
5.2	Naval integrated permanent structures	739
5.2.1	Flight decks (vertical)	739
5.2.2	Stern ramps (launch and recovery systems)	740
5.2.3	Blast resistant structures	741
5.3	Naval modular flexible structures	742
5.3.1	Mission bays	742
5.3.2	Weapon modules	743
5.3.3	Advanced enclosed masts/sensor (enclosed aperture stations)	743
5.4	Conclusion	744
6	Naval mast design	744
6.1	Introduction	744
6.2	Types of naval masts	745
6.3	Materials (composite vs. steel vs. aluminum)	746
6.4	Loads	747
6.4.1	Weight of equipment	747
6.4.2	Environmental loadings (includes wind and seaway loads)	747
6.4.3	Thermal	747
6.4.4	Shock and blast	747
6.4.5	Load combinations	747
6.5	Vibration and resonance	748
6.6	Structural analysis and design	748
6.7	Other considerations	749
6.8	Classification society rules for mast design	749
6.9	Conclusions	749
7	Progressive collapse analysis and residual strength assessment	750
7.1	Introduction	750
7.2	Progressive collapse method overview	750
7.3	Development of the progressive collapse method	751
7.4	Residual strength assessment by progressive collapse method	751
7.5	Use of FEA for progressive collapse assessment	752
7.6	Progressive collapse analysis within classification society rules	752
7.7	Discussion and conclusions	753
8	High speed naval craft	754
8.1	Naval applications	754
8.2	Defining a high speed craft	755
8.2.1	Principles	755
8.2.2	Hull form	756
8.2.3	Standards and regulations	756
8.3	Defining operational limitations	757
8.3.1	Operational profile	757
8.3.2	Operational envelope	757

8.4	Accelerations effects	758
8.4.1	Slamming	758
8.4.2	Human factors	758
8.4.3	Fatigue	759
8.5	Material technologies	759
8.5.1	Steel	759
8.5.2	Aluminium	760
8.5.3	Fibre reinforced plastics (FRP)	760
8.6	Unmanned naval high speed craft	760
8.7	Classification society rules	760
8.8	Conclusion	761
9	Benchmark studies	761
9.1	Whipping response of ship	761
9.1.1	Introduction	761
9.1.2	UNDEX bubble phenomena	762
9.1.3	Experimental investigations	763
10	Discussions and conclusions	764
	References	766
	Report of Committee V.6: Arctic technology	769
1	Introduction	771
1.1	Limitations	772
2	Present design methods	772
2.1	Ships	772
2.1.1	Rules	773
2.1.2	First principles	776
2.2	Offshore structures	780
2.2.1	Rules	783
2.2.2	First principles	784
2.3	Validation methods	788
3	Case 1: Ship transportation in arctic waters—the NSR	790
4	Case 2: Floating offshore structures in arctic waters	793
5	Future perspectives and challenges	795
5.1	Numerical simulations	797
5.2	Ice induced fatigue	799
6	Summary and recommendations	801
	Acknowledgments	802
	References	802
	Report of Committee V.6: Arctic technology annex	807
1	Brief offshore structures code summaries	809
2	Full scale ice load measurement campaigns	813
3	References	816
	Report of Committee V.7: Structural longevity	817
1	Introduction	820
1.1	Background & mandate	820
1.2	Relationship with other ISSC committees	820
2	Lifecycle assessment & management for structural longevity	821
2.1	Introduction	821
2.2	The need for lifecycle assessment and management	821
2.3	Conclusions	823

3	Current practice	823
3.1	Introduction	823
3.2	The role of regulators and classification societies	823
3.3	Classification rules and guidance	824
3.4	Commercial shipping vessels	825
3.4.1	International trading vessels	825
3.4.2	High-speed craft (HSC)	826
3.4.3	Vessels operating in inland waterways	826
3.5	Offshore structures	826
3.5.1	Offshore drilling units	826
3.5.2	Floating production storage and offloading (FPSO) units	827
3.5.3	Fixed production platforms	827
3.6	Naval vessels	827
3.7	Conclusions	828
4	Prediction of longevity	828
4.1	Introduction	828
4.2	Prediction of longevity of merchant ships	828
4.2.1	Prediction of corrosion	829
4.2.2	Fatigue strength prediction	829
4.2.3	Buckling prediction	830
4.3	Prediction of longevity of fixed offshore structures	830
4.4	Conclusions	830
5	Prevention & repair of structural failures	831
5.1	Introduction	831
5.2	Prevention of failure – design stage	831
5.2.1	Corrosion protection	831
5.2.2	Material selection	832
5.2.3	Structural design	832
5.3	Prevention of failure – operation	833
5.3.1	Maintenance & inspection	833
5.3.2	Repair and rehabilitation	834
5.4	Conclusions and recommendations	836
6	Inspection methods & techniques	836
6.1	Introduction	836
6.2	Inspection execution	837
6.3	Inspection techniques	837
6.4	Limitations	838
6.5	Conclusions and recommendations	839
7	Sensing technologies	839
7.1	Introduction	839
7.2	Passive systems	840
7.2.1	Strain	840
7.2.2	Acoustic emission	840
7.2.3	Vibrations	841
7.2.4	Crack	841
7.2.5	Corrosion	841
7.2.6	Acceleration	841
7.2.7	Metocean information	842
7.3	Active system	842
7.3.1	Impedance-based methods	842
7.3.2	Lamb wave-propagation methods	843

7.4	Data acquisition and processing	844
7.5	Sensor network, wired and wireless	844
7.6	Maturity of structural hull monitoring systems	844
8	Methodologies for using inspection & sensed data	845
8.1	Introduction	845
8.2	Operational advice	846
	8.2.1 Identifying loading to stay within safe operating envelope	846
	8.2.2 Quantifying operational loading and changes	848
8.3	Lifecycle management advice	848
	8.3.1 Condition based maintenance (CBM)	850
	8.3.2 Reliability centered maintenance	850
	8.3.3 Reliability based inspections	850
8.4	Design update based on lessons learned from analysis of failures	851
8.5	Discussion	851
8.6	Conclusions	851
9	Life time extension, comparison outside & within the maritime industry	852
9.1	Introduction	852
9.2	Lifetime extension of existing structures	852
9.3	Other industries	854
9.4	Differences in approaches for ships, offshore structures, and other marine structures (ranging from navy to renewable energies)	855
9.5	Conclusions	855
10	Conclusions & recommendations	856
10.1	Conclusions	856
10.2	Recommendations	856
	References	857
	Report of Committee V.8: Risers and pipelines	865
1	Introduction	867
2	New design concepts	867
2.1	Latest design practice of flexible risers	867
	2.1.1 Present application envelope	867
	2.1.2 Deep water	868
	2.1.3 Shallow water	868
	2.1.4 Singing risers	868
	2.1.5 Hybrid towers	869
2.2	Latest design practice of pipeline	870
3	Dynamic response investigation review	871
3.1	Riser	871
	3.1.1 Wave load induced dynamic response	871
	3.1.2 VIV	873
3.2	Free span VIV of pipeline	878
	3.2.1 Assessment	878
	3.2.2 Mitigation	879
4	Soil-pipeline interaction	879
4.1	Introduction	879
4.2	Soil behavior near pipelines	880
4.3	Pipeline as-laid embedment and riser touchdown	880
4.4	Lateral pipe-soil interaction	881
4.5	Axial pipe-soil interaction	882
4.6	Pipeline stability during trenching and backfilling	882
4.7	Pipeline stability during sediment transport and liquefaction	883

5	Failure modes of risers and pipelines	884
5.1	Steel riser and pipelines	884
5.1.1	Buckling (buckle propagation), collapse and fatigue failure	884
5.1.2	Corrosion	885
5.1.3	Crack	886
5.1.4	Erosion	886
5.2	Flexible pipes	886
5.2.1	Failure modes	886
5.2.2	Design analysis	886
5.2.3	Monitoring	887
6	Installation	888
6.1	Risers	888
6.2	Pipelines	888
7	Inspection and repair	889
7.1	Risers	889
7.2	Pipelines	891
7.2.1	Maintenance	891
7.2.2	Inspection	891
7.2.3	Repair	892
8	Conclusions	893
	References	895
	Author index	903

Preface

The first volume contains the eight Technical Committee reports presented and discussed at the 19th International Ship and Offshore Structures Congress (ISSC 2015) in Cascais, Portugal, 7–10 September 2015 and the second volume contains the reports of the eight Specialist Committees. The Official discussor's reports, all floor discussions together with the replies by the committees will be published after the Congress in electronic form.

The Standing Committee of the 19th International Ship and Offshore Structures Congress comprises:

Chairman: Carlos Guedes Soares
Jørgen Amdahl
Yoo Sang Choo
Weicheng Cui
Segen Estefen
Stefano Ferraris
Wolfgang Fricke
Masahiko Fujikubo
Mirek Kaminski
Merv Norwood
Jeom Kee Paik
Jean-Yves Pradillon
Manolis Samuelides
Ajit Sheno
Christina Wang

Secretary: Yordan Garbatov

On behalf of the Standing Committee, we would like to thank DNV-GL, ClassNK (Nippon Kaiji Kyokai), ABS (American Bureau of Shipping), CCS (China Classification Society), KR (Korean Register), and LR (Lloyd's Register) for sponsoring ISSC 2015.

Carlos Guedes Soares
Chairman

Yordan Garbatov
Secretary

Cascais, September, 2015