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COMPIT‘13

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Index

Volker Bertram, Milovan Peric
Advanced Simulations for Offshore Industry Applications 7

Valery Mrykin, Alexander Leshchina, Alexander Roshchin, Manucher Dorri
Use of Current Computer Simulation Technologies in the Development of Ship Control Systems 21

David Andrews
The True Nature of Ship Concept Design – And What it Means for the Future Development of CASD 33

Daniele Peri
Automatic Tuning of Metamodels for Optimization 51

Gabriele Bruzzone, Marco Bibuli, Massimo Caccia, Enrica Zereik, Giorgio Bruzzone, Mauro Giacopelli, Edouard Spirandelli
Cooperative Autonomous Robotic Towing System – Exploitation of Autonomous Marine Vehicles in Emergency Towing Procedures 63

Heikki Hansen, Karsten Hochkirch
Lean ECO-Assistant Production for Trim Optimisation 76

Karsten Hochkirch, Benoit Mallol
On the Importance of Full-Scale CFD Simulations for Ships 85

Morgan C. Parker, David J. Singer
The Impact of Design Tools: Looking for Insights with a Network Theoretic Approach 96

Herbert J. Koelman
A Mid-Term Outlook on Computer Aided Ship Design 110

Paul Groenenboom, Paul Croaker, Arigiris Kamoulakos, Fouad El-Khaldi
Innovative Smoothed Particle Hydrodynamics for Wave Impact Simulation on Ships and Platforms 120

Geir L. Olsen
e-Navigation Starts with e-VoyagePlanning 135

Antonio Rodríguez-Goñi, Leonardo Fernández-Jambrina
A CAD Development Strategy for the Next Years 143

Eloïse Croonenborghs, Thomas Sauder, Sébastien Fouques, Svein-Arne Reinholdtsen
CFD Prediction of Wind and Current Loads on a Complex Semi-Submersible Geometry 157

Thomas Gosch
Simulation-Based Design Approach for Safer RoPax Vessels 167

Thomas Porathe, Hans-Christoph Burmeister, Ørnulf Jan Rødseth
Maritime Unmanned Navigation through Intelligence in Networks: The MUNIN project 177

Jukka Ignatius, Jan-Erik Räisänen, Kalevi Tervo, Jan-Jaap Stoker, Tim Ellis
A Comprehensive Performance Management Solution 184
Verónica Alonso, Carlos Gonzalez, Rodrigo Pérez
Efficient Use of 3D Tools at Early Design Stages 195

Alberto Alvarez, Jochen Horstmann
Towards the Estimation of Directional Wave Spectra from Measured Glider Responses 208

Ju Young Kang
A Combination of Morphing Technique and Cartesian Grid Method for Rapid Generation of Objects and their Performances 215

Thomas Koch, Eduardo Blanco-Davis, Peilin Zhou
Analysis of Economic and Environmental Performance of Retrofits using Simulation 225

Luigi Ostuni, Andrea De Pascalis, Francesca Calabrese, Marco Cataldo, Luisa Mancarella, Alessandro A. Zizzari, Angelo Corallo
An On-board Expert System for Damage Control Decision Support 238

Rachel Pawling, David Andrews, Rebecca Piks, David Singer, Etienne Duchateau, Hans Hopman
An Integrated Approach to Style Definition in Early Stage Design 248

Nicolas Rox, Ole Christian Astrup
Streamlining the Steel Design Process by Linking Design and Rule Scantling Tools 264

Fedor Titov, Axel Friedewald
Handling Human Models in Virtual Reality Applications with MS Kinect 274

Pyry Åvist, Jussi Pyörre
Modeling the Impact of Significant Wave Height and Wave Vector using an On-board Attitude Sensor Network 283

Sami Salonen, Aatos Heikkinen
Robust Characterization of Ship Power Plant Fuel Efficiency 293

Paul Roberts, Tom Macadam, Neil Pegg
Multiple Simulation Assessments from a Single Ship Product Model 301

Darren Larkins, Denis Morais, Mark Waldie
Democratization of Virtual Reality in Shipbuilding 316

Ole John, Michael Böttcher, Carlos Jahn
Decision Support for the Crew Scheduling Problem in Ship Management 327

Nick Danese, Runar Aasen
Exploiting Weight Data to Support Engineering and Corporate Decision-Making Processes 334

Stefan Harries, Erik Dölerud, Pierre C. Sames
Port Efficiency Simulations for the Design of Container Ships 348

David Thomson, Philippe Renard
The Digital Handover – Shipyards as Producers of Life-Cycle Maintenance Models 363
Andrea Caiti, Vincenzo Calabrò, Francesco Di Corato, Daniele Meucci, Andrea Munafò
Distributed Cooperative Algorithms for Autonomous Underwater Vehicles in Marine Search Missions 380

George Korbetis, Dimitris Georgoulas
Efficient Use of CAE Pre- and Post-Processing in Offshore Structures Design 390

Andreas Abel, Uwe Schreiber, Erik Werner
Bridging the Gap between Steady-State and Transient Simulation for Torsional Vibrations under Ice Impact 402

Henner Eisen
The Spectral Method Re-Engineered: High-Performance Finite-Element-Based Fatigue Assessment Processes for Ship Structures 413

Heiko Duin, Markus Lehne, Niklas Fischer, Christian Norden
Application of Cross-Impact Analysis to Evaluate Innovations in the Cruise Industry 425

Yi-Fang Hsieh, Sing-Kwan Lee, Zhiyong Zhou
Design Evaluation of Energy-Saving Devices for Full Form Ship Propulsion 437

Deguang Yan, Hung-Pin Chien, Kai Yu, Sing-Kwan Lee, Jer-Fang Wu
CFD Virtual Model Basin Development for Offshore Applications 450

Shaun Hunter, Justin Freimuth, Nick Danese
Utilizing a Robust Fatigue Screening Process for Initial Design and Throughout the Ship Life-Cycle 466

Runar Aasen, Patrick Roberts, Nick Danese, Lawrence Leibman
Utilizing CAD/CAM Models for Ongoing Weight Estimation and Control 480

Amirouche Amrane, Abbas Bayatfar, Philippe Rigo
An Optimisation Methodology for Ship Structural Design using CAD/FEM Integration 491

Index of authors 498

Call for Papers for next COMPIT
Advanced Simulations for Offshore Industry Applications

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Abstract

An overview of simulations for assorted advanced engineering analyses in the offshore industry is given, focussing on the benefits for the business processes of the customers. The analyzed structures include fixed and floating offshore platforms, related ships such as supply vessels, and selected equipment. The analysis looks at the main operational problems such as ensuring low environmental impact, high availability and compliance with regulations, as well as promoting innovative designs and procedures. The role of assorted advanced simulations (structure, noise & vibration, fluid dynamics, aerodynamics, installation simulations, etc) in this context is illustrated by case studies taken predominantly from the experience of GL Group with a strong focus on industry projects and recent research projects.

1. Introduction

Traditionally, design and operation of ships and offshore structures have been based on experience. This is still true to some extent, but increasingly we rely on “virtual experience” from dedicated simulations. Scope and depth of these simulations guiding our decisions have developed very dynamically over the past decade. In previous publications, we have focussed on the technical aspects of simulations, Bertram and Couser (2007), Bertram (2009a,b), Peric and Bertram (2011). In the present paper, we want to focus instead on the benefits of simulations from the customer’s point of view. The “customer” may be the designer, builder or operator of an offshore installation, or any subcontractor, i.e. any business unit outsourcing services based on the special competence of simulation experts. From a customer perspective, simulations serve to support business processes through

- Ensuring low environmental impact
- Ensuring high availability / utilisation
- Promoting innovative designs and procedures
- Ensuring compliance

These items are discussed in the following sections in the context of offshore installations and their supporting fleet of ships for installation, maintenance and supply.

2. Ensuring low environmental impact

Accidents like the “Exxon Valdez” and the “Deepwater Horizon” have had profound impact on the offshore industry. This does not only concern direct liability claims, but also indirect business impact due to impaired image with other stakeholders, most notably customers. Safety, also environmental safety, concerns both design and operation.

Designs should be sufficiently strong to avoid problems in usual operation, including rare events. International and national regulations as well as classification society rules are taken as guidelines for what has to be assumed as worst-case scenario, e.g. “the highest wave to be expected in this region within 100 years”. The specification of such worst-case scenarios and associated probabilities gains in importance within the context of risk-based design, but will not be discussed further here. Industry practice is that the simulation expert follows user specifications or common practice. In most cases, the largest uncertainty in the structural assessment comes through the assumed loads. Detailed structural analyses therefore require generally dedicated other simulations to prescribe load distributions (varying in space and time):
• Long-term spectral distributions of wave loads, based on linear seakeeping methods, for fatigue analyses, e.g. discussed in Bertram (2011), Bertram and Gualeni (2011). For many seakeeping issues, linear analyses (assuming small wave height) are appropriate and frequently applied due to their efficiency. Linear approaches are very fast and allow thus the investigation of many parameters (frequency, wave direction, ship speed, etc.). They may also be used for most mooring applications, estimates for second-order drift forces, and for multi-body analyses in moderate waves.

• Extreme wave scenarios, including freak waves, require free-surface RANSE (Reynolds-averaged Navier-Stokes equations) simulations, Fig. 1, e.g. El Moctar et al. (2007). Such free-surface RANSE simulations are generally employed for cases with strongly nonlinear geometries of waves and object. The computations require usually parallel computer hardware and CFD (computational fluid dynamics) experts. Combining intelligently linear frequency-domain methods with nonlinear time-domain simulations allows exploiting the respective strengths of each approach. For example, the linear analysis identifies the most critical parameter combination for a ship response. The subsequent RANSE simulation determines motions, loads and free surface (green water on deck).

• Impact loads, using free-surface RANSE solvers. Impact loads appear for slamming and sloshing analyses, Fig. 2, Fig. 3, Bertram et al. (2003), Peric et al. (2007), Morch et al. (2009). The approach has been extensively validated. Mostly, these simulations assume weak fluid-structure interaction, i.e. the fluid dynamic simulation specifies the loads for the structural finite-element analyses (FEA), but the deformation is not considered for the CFD simulation. However, strong fluid-structure interaction considering also the effect of the structural response on the fluid dynamics is feasible, Oberhagemann et al. (2008), El Moctar et al. (2011). Applications include springing and whipping for ships, and sloshing for tanks with very flexible membranes.
As a special case, ice loads may be considered. Here, simulations of offshore structures in brash ice consider e.g. the loads for dynamic positioning of drill ships, Wang and Derradj-Aouat (2011). LS-DYNA, a finite-element code usually used for ship-ship collision analyses can be applied for these simulations. Vroegrijk (2011) employs the commercial CFD code StarCCM+ with the Discrete Element Method (DEM) option to model brash ice flows around an obstacle. But more frequently dedicated software is used, Fig.4, e.g. Puntigliano (2003), Liu et al. (2010), Lubbad and Løset (2011).

Strength analyses have reached a mature state and are widely applied in the design of offshore structures to ensure sufficiently strong designs. Finite-element analyses (FEA) for global strength within the elastic material domain are widely applied to ships, offshore structures, and subsystems (e.g. gearboxes, engines, cranes, risers, pipelines, etc.). Particularly for offshore platforms and FPSOs, frequently more sophisticated analyses are performed, such as fatigue analyses or collision analyses, Fig.5. Collision analyses play a major role in (passive) safety against oil spills. Based on extensive experience with such simulations, Germanischer Lloyd provided as first classification society a standard for evaluation and approval of alternative solutions for design and construction of tankers, Zhang et al. (2004). Today, collision analyses are regularly performed for ships with class notation “COLL” and for offshore wind farms where authorities require proof of collision friendliness.

Also, operational guidelines may be based on simulations. This concerns in particular accident response procedures. Progress in simulation techniques and computer hardware have led to a multitude of applications that were previously not possible at all or approximated by more expensive and/or less accurate model tests, e.g.:
• Towing of damaged structures
After an accident, damaged ships or offshore structures often must be towed to repair sites. Typically, the initial accident will impair the strength of the structure, but may also affect residual freeboard and stability. This must be considered for the towing. CFD simulations for towed systems manoeuvring in waves represent the state-of-the-art approach for the hydrodynamic issues, Fig.6. FEA simulations determine stress distributions in damaged structures, considering the actual hull structure condition including corrosion.

• Oil spills
Multi-phase flows, i.e. flows with several fluids of differing density and viscosity, can be simulated by all major commercial CFD codes. For oil spills, oil and water are considered, sometimes also air (when waves or sloshing plays a role). Vasconcellos and Alho (2012) give a typical application for an oil spill in an FPSO, Fig.7.

Fig.6: Tug-tow system in waves

Fig.7: Oil spill simulation, Vasconcellos and Alho (2012)

Fig.8: Mesh for offshore superstructure and CFD simulated flow around it, Peric and Bertram (2011)

Fig.9: Gas dispersion in closed working areas after (potential) leak

Fig.10: Temperature distribution in supersonic gas leak
**Gas dispersion**

Aerodynamic flows around offshore structures can be computed in great detail, Fig.8, with or without added smoke or gas. From a simulation point of view, gas dispersion is very similar to fluid dispersion. The same techniques and software can be applied, albeit with different density and viscosity. In addition, for gas (including smoke) dispersion, thermal processes and thermal buoyancy play usually a significant role and must be reflected in the simulation model. Such simulations may concern external flows, typically near crew quarters or helidecks, or internal flows in closed working or living areas, Fig.9. They may also cover extreme temperatures or speeds, including supersonic, explosive leaks, Fig.10.

**Disposal /cleaning operations**

Multi-phase flow simulations have been used for decision support in cleaning offshore structures, in regular operation or in preparation for disposal, Fig.11. Simulations identify for example stagnant flow regions in tanks or the effectiveness of cleaning procedures.

![Fig.11: Simulation of stagnant or low-velocity regions in tank (sediment accumulation)](image)

3. **Ensuring high availability**

Offshore structures usually have much higher down-time costs than cargo ships. Consequently, much higher focus is placed on ensuring high availability of these structures. High availability is mainly achieved through three levers, “design for availability” (system robustness), “monitoring for availability” (condition based maintenance to avoid downtime), and fast “trouble-shooting”. The role of simulations in this context will be discussed in the following:

**Design for availability**

Failure mode and effect analyses (FMEA) or related formal risk assessment techniques are widely applied to offshore systems and subsystems. A “system” in this sense is not just the technical object, but includes also operational procedures. Operational guidelines for risk mitigation contribute significantly to ensure high availability. A typical example are specifications for operational limits (sea states) for installation, maintenance and operation, both of offshore installations (platforms, FPSOs, etc), and offshore supply vessels. Such operational limits are determined based e.g. on seakeeping simulations. The appropriate simulation tools depend on required accuracy, geometry of the object (slender monohull, catamaran, large dis-