Response predictions using the observed autocorrelation function
This article studies a procedure that facilitates short-time, deterministic predictions of the wave-induced motion of a marine vessel, where it is understood that the future motion of the vessel is calculated ahead of time. Such predictions are valuable to assist in the execution of many marine operations (crane lifts, helicopter landings, etc.), as a specific prediction can be used to inform whether it is safe, or not, to carry out the particular operation within the nearest time horizon. The examined prediction procedure relies on observations of the correlation structure of the wave-induced response in study. Thus, predicted (future) values ahead of time for a given time history recording are computed through a mathematical combination of the sample autocorrelation function and previous measurements recorded just prior to the moment of action. Importantly, the procedure does not need input about the exciting wave system, and neither does it rely on o-line training. In the article, the prediction procedure is applied to experimental data obtained through model-scale tests, and the procedure's predictive performance is investigated for various irregular wave scenarios. The presented results show that predictions can be successfully made in a time horizon corresponding to about 8-9 wave periods ahead of current time (the moment of action).
This paper presents a novel method for estimating the sea state parameters based on the heave, roll and pitch response of a vessel in dynamic positioning (DP), i.e., without forward speed. The algorithm finds the wave spectrum estimate from the response measurements by directly solving a set of linear equations, and as a result it is computationally efficient. The main vessel parameters are required as input. Apart from this the method is signal-based, with no assumptions on the wave spectrum shape. Performance of the proposed algorithm is demonstrated on full-scale experimental DP data of a vessel in three different sea states at head, bow, beam, quartering and following sea waves, respectively.
A brute-force spectral approach for wave estimation using measured vessel responses

The article introduces a spectral procedure for sea state estimation based on measurements of motion responses of a ship in a short-crested seaway. The procedure relies fundamentally on the wave buoy analogy, but the wave spectrum estimate is obtained in a direct - brute-force - approach, and the procedure is simple in its mathematical formulation. The actual formulation is extending another recent work by including vessel advance speed and short-crested seas. Due to its simplicity, the procedure is computationally efficient, providing wave spectrum estimates in the order of a few seconds, and the estimation procedure will therefore be appealing to applications related to realtime, onboard control and decision support systems for safe and efficient marine operations. The procedure's performance is evaluated by use of numerical simulation of motion measurements, and it is shown that accurate wave spectrum estimates can be obtained for all wave directions in short-crested waves, taking the wave system to be composed by both wind generated sea and swell.

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A concise account of techniques available for shipboard sea state estimation

This article gives a review of techniques applied to make sea state estimation on the basis of measured responses on a ship. The general concept of the procedures is similar to that of a classical wave buoy, which exploits a linear assumption between waves and the associated motions. In the frequency domain, this assumption yields the mathematical relation between the measured motion spectra and the directional wave spectrum. The analogy between a buoy and a ship is clear, and the author has worked on this wave buoy analogy for about fifteen years. In the article, available techniques for shipboard sea state estimation are addressed, but with a focus on only the wave buoy analogy. Most of the existing work is based on methods established in the frequency domain but, to counteract disadvantages of the frequency-domain procedures, newer studies are working also on procedures formulated directly in the time domain. Sample results from several studies are included, and the main findings from these are mentioned.

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Authors: Nielsen, U. D. (Intern)
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Deterministic Predictions of Vessel Responses Based on Past Measurements

The paper deals with a prediction procedure from which global wave-induced responses can be deterministically predicted a short time, 10-50 s, ahead of current time. The procedure relies on the autocorrelation function and takes into account prior measurements only; i.e. knowledge about wave conditions is not needed. In the present study, the procedure is examined on artificially simulated data that represents the measurements. It is shown that predictions, in most cases, can be made fairly accurate up to 20 s ahead of current time; for longer periods ahead the accuracy reduces somewhat. The sensitivity to the amount of prior data is investigated.

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Authors: Nielsen, U. D. (Intern), Jensen, J. J. (Intern)
Intact stability analysis of dead ship conditions using FORM

The IMO Weather Criterion has proven to be the governing stability criteria regarding minimum GM for e.g. small ferries and large passenger ships. The formulation of the Weather Criterion is based on some empirical relations derived many years ago for vessels not necessarily representative for current new buildings with large superstructures. Thus it seems reasonable to investigate the possibility of capsizing in beam sea under the joint action of waves and wind using direct time domain simulations. This has already been done in several studies. Here it is combined with the First Order Reliability Method (FORM) to define possible combined critical wave and wind scenarios leading to capsize and corresponding probability of capsize. The FORM results for a fictitious vessel are compared with Monte Carlo simulation and good agreement is found at a much lesser computational effort. Finally, the results for an existing small ferry will be discussed in the light of the current weather criterion.
Statistical prediction of parametric roll using FORM

Previous research has shown that the First Order Reliability Method (FORM) can be an efficient method for estimation of outcrossing rates and extreme value statistics for stationary stochastic processes. This is so also for bifurcation type of processes like parametric roll of ships. The present paper discusses this solution procedure with a focus on the computational efficiency of FORM as compared with Monte Carlo Simulation (MCS).

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Web of Science (2016): Indexed yes
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Transformation of a wave energy spectrum from encounter to absolute domain when observing from an advancing ship

The article presents a practical approach to transform a wave energy spectrum from encounter domain to absolute domain. This problem has its specific relevance, when shipboard sea state estimation is conducted by the buoy analogy; notably for some particular implementation solving for the sea state directly in the encounter domain. The encounter domain is that observed from a ship when it advances in a seaway, whereas the absolute domain is that corresponding to making observations from a fixed point in the inertial frame. Spectrum transformation can be uniquely carried out if the ship sails “against” the waves (beam to head sea) but in following sea conditions there exists no unique solution to the problem. Instead, a reasonable approach valid for practical engineering must be applied, and the article outlines one viable solution that can be used to transform a wave spectrum from encounter to absolute domain. Specifically, two pseudo algorithms are presented, and good performance is achieved with both algorithms when they are tested at different operational scenarios.
An attempt to define critical wave and wind scenarios leading to capsize in beam sea

The IMO Weather Criterion has proven to be the governing stability criterion regarding minimum GM for e.g. small ferries and large passenger ships. The formulation of the Weather Criterion is based on some empirical relations derived many years ago for vessels not necessary representative for current new buildings with large superstructures. Thus it seems reasonable to investigate the possibility of capsizing in beam sea under the joint action of waves and wind using direct time domain simulations. This has already been done in several studies. Here it is combined with the First Order Reliability Method to define possible combined critical wave and wind scenarios leading to capsizing and corresponding probability of capsize. The results for a fictitious vessel are compared with Monte Carlo simulation and good agreement is found at a much lesser computational effort. Finally, the results for a large container vessel and a small ferry will be discussed in the light of the current weather criterion.

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Authors: Jensen, J. J. (Intern), Choi, J. (Intern), Kristensen, H. O. H. (Intern), Nielsen, U. D. (Intern), Erichsen, H. (Ekstern), Tvedt, E. I. (Ekstern)
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Publication date: 2016

A Review of Sea State Estimation Procedures Based on Measured Vessel Responses

The operation of ships requires careful monitoring of the related costs while, at the same time, ensuring a high level of safety. A ship’s performance with respect to safety and fuel efficiency may be compromised by the encountered waves. Consequently, it is important to estimate the surrounding seastate, and any shipboard decision support system (DSS) needs to have as input information about the encountered waves for the DSS to be the most accurate and reliable. Trustful means for sea state estimation (SSE) include floating wave rider buoys. However, for ships navigating the oceans, wave rider buoys are not practical, as sea state information in real-time and at the actual geographical position of the ship is needed. On the other hand, the analogy between a ship and a floating buoy naturally suggests to using the ship itself as a wave buoy. This paper presents a status on techniques for shipboard SSE using measured vessel responses, resembling the concept of traditional wave rider buoys. Moreover, newly developed ideas for shipboard sea state estimation are introduced. The presented material is all based on the author’s personal experience, developed within extensive work on the subject in the last fifteen years; work conducted alone and together with national as well as international colleagues.

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A Study on the uncertainty and sensitivity in numerical simulation of parametric roll

Uncertainties related to numerical modelling of parametric roll have been investigated by using a 6-DOFs model with nonlinear damping and roll restoring forces. At first, uncertainty on damping coefficients and its effect on the roll response is evaluated. Secondly, uncertainty due to the "effective (equivalent) wave" concept in calculation of restoring moment is studied. Finally, uncertainty to roll response from different methods of GZ calculation has been checked. It is found that the equivalent wave concept is sufficiently accurate for the purpose of GZ calculation. Two different GZ approximations give a good agreement with direct calculation method if relevant coefficients have been properly found in the fitting.

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Estimation of waves and ship responses using onboard measurements
This thesis focuses on estimation of waves and ship responses using ship-board measurements. This is useful for development of operational safety and performance efficiency in connection with the broader concept of onboard decision support systems.

Estimation of sea state is studied using a set of measured ship responses, a parametric description of directional wave spectra (a generalised JONSWAP model) and the transfer functions of the ship responses. The difference between the spectral moments of the measured ship responses and the corresponding theoretically calculated moments formulates a cost function. A set of wave parameters, characterising the directional wave spectrum, is estimated through an optimisation problem using global search basin with proper constraints. This approach applies a sequential partitioning procedure, which is able to classify swell and wind sea events using wind information.

The model is tested on simulated data based on known unimodal and bimodal wave scenarios. The wave parameters in the output are then compared with the true wave parameters. In addition to the numerical experiments, two sets of full-scale measurements from container ships are analysed. Herein, the validation of the estimation method is assessed by comparing the results with the wave data from other tools, such as wave radar data and hindcast data. The results show that the developed method is reasonably accurate.

Automatic selection of a set of responses to be used for wave estimation is also studied using a sensitivity analysis of the wave parameters. This selection depends on the waves and the operational condition of the ship. Therefore, the method can be utilised based on initial knowledge about the waves and the operational condition in a specific location.

A dynamic trend model is proposed for tracking the evolution of the wave parameters during the voyage. This provides a prediction of the wave parameters, e.g. 20 minutes ahead of the measurements. Given the predicted parameters, a wave spectrum model and the transfer functions, forecasts of different wave-induced responses are made. The predicted variances of the responses are compared with actual measurements. The relatively good agreement in this comparison validates the model and the optimisation method. Finally, an uncertainty analysis of the presented approach is implemented to assess the reliability of the method.
Estimation of wind sea and swell using shipboard measurements – A refined parametric modelling approach

Shipboard wave estimation has been of interest in recent years for the purpose of decision support. In this paper, estimation of sea state is studied using ship responses and a parametric description of directional wave spectra. A set of parameters, characterising a given wave spectrum is estimated through an optimisation problem using global search basin with proper constraints. The cost function is established based on the difference between the energies of a set of measured ship responses and the corresponding theoretical spectral moments. A partitioning procedure is applied, which is able to separate swell components from wind seas.
Evaluation of Shipboard Wave Estimation Techniques through Model-scale Experiments

The paper continues a study on the wave buoy analogy that uses shipboard measurements to estimate sea states. In the present study, the wave buoy analogy is formulated directly in the time domain and relies only partly on wave-vessel response amplitude operators (RAOs), which is in contrast to all previous works that either are formulated in the frequency domain and/or depend entirely on RAOs. Specifically, the paper evaluates a novel concept for wave estimation based on combined techniques using a wave frequency estimator, not dependent on RAOs, to detect wave frequency and, respectively, nonlinear least squares fitting to estimate wave amplitude and phase. The concept has been previously tested with only numerical simulations but in this study the techniques are applied to model-scale experiments. It is shown that the techniques successfully can be used to estimate the wave parameters of a regular wave train.

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Improved Wave-vessel Transfer Functions by Uncertainty Modelling

This paper deals with uncertainty modelling of wave-vessel transfer functions used to calculate or predict wave-induced responses of a ship in a seaway. Although transfer functions, in theory, can be calculated to exactly reflect the behaviour of the ship when exposed to waves, uncertainty in input variables, notably speed, draft and relative wave heading, often compromises results. In this study, uncertainty is applied to improve theoretically calculated transfer functions, so they better fit the corresponding experimental, full-scale ones. Based on a vast amount of full-scale measurements data, it is shown that uncertainty modelling can be successfully used to improve accuracy (and reliability) of theoretical transfer functions.

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Selection of the optimum combination of responses for Wave Buoy Analogy - An approach based on local sensitivity analysis

One method to estimate the wave spectrum onboard ships is to use measured ship responses. In this method, known also as Wave Buoy Analogy, amongst various responses that are available from sensor measurements, a couple of responses (at least three) are usually utilized. Selection of the best combination of ship responses is important. Optimally, this selection should not be implemented manually on board applications. Therefore, availability of an automatic response selection procedure would be a great advantage for decision support. In this paper, a local sensitivity analysis is applied to evaluate the importance of individual responses in sea state estimation. The sensitivity factor is defined by calculation of the partial derivatives of wave parameters with respect to the variance of individual responses.

New Concepts for Shipboard Sea State Estimation

The wave buoy analogy is a tested means for shipboard sea state estimation. Basically, the estimation principle resembles that of a traditional wave rider buoy which relies, fundamentally, on transfer functions used to relate measured wave-induced responses and the unknown wave excitation. This paper addresses however a newly developed concept of the wave buoy analogy but the approach presented herein is, on the contrary, not relying exclusively on transfer functions. Instead, the method combines a signal-based part, estimating wave frequency, and a model-based part, estimating wave amplitude and phase, where only the model-based part depends on transfer functions whereas the signal-based part relies on the measured vessel response alone. Case studies in terms of hypothetical examples show that the method is capable to reconstruct fully the wave elevation process of a sinusoidal regular wave; which include estimation of the wave’s frequency, amplitude and phase. At this stage, the method is far from being a useful means in practical, real-situation applications but the method provides, indeed, a valuable step towards developing new approaches for shipboard sea state estimation.
Prediction of First-Order Vessel Responses with Applications to Decision Support Systems

The paper presents a practical and simple approach for making vessel response predictions. Features of the procedure include a) predictions which are scaled so to better agree with corresponding true, future values to be measured at the time the predictions apply at; and b) predictions that are assigned an uncertainty measure to reflect a level of confidence. The approach is tested with full-scale data and the obtained results/predictions agree well with measured values. Potentially, the procedure is therefore very useful in future developments of general decision support systems.

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Authors: Nielsen, U. D. (Intern), Iseki, T. (Ekstern)
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Sea State Estimation Using Model-scale DP Measurements

Complex marine operations are moving further from shore, into deeper waters, and harsher environments. The operating hours of a vessel are weather dependent, and good knowledge of the prevailing weather conditions may ensure cost-efficient and safe operations. This paper considers the estimation of the peak wave frequency of the on-site sea state based on the vessel’s motion in waves. A sea state can be described by significant wave height, peak wave frequency,
wave direction, and often wind speed and direction are added as well. The signal-based algorithm presented in this paper is based on Fourier transforms of the vessel response in heave, roll and pitch. The measurements are used directly to obtain an estimate of the peak frequency of the waves. Experimental results from model-scale offshore ship runs at the Marine Cybernetics Laboratory (MCLab) at NTNU demonstrate the performance of the proposed sea state estimation algorithm.

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Study on Short-term Variability of Ship Responses in Waves
Short-term variability of ship responses is investigated by cross-spectrum analysis. In a steady state condition, it is well known that a certain length of sampled data is required for stable results of the spectral analysis. However, the phase lag between responses, in terms of the phase angle of the cross-spectra, has not been discussed in detail. Using long stationary time series, the transition of amplitudes and relative phase angles of the cross-spectra has been investigated by iterative analyzes with a few seconds of time shifting. In the results, the short-term variability of the relative phase angle was observed. In effect, the variability may compromise the accuracy of the wave buoy analogy.

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Trend modelling of wave parameters and application in onboard prediction of ship responses

This paper presents a trend analysis for prediction of sea state parameters onboard ships during voyages. Given those parameters, a JONSWAP model and also the transfer functions, prediction of wave induced ship responses are thus made. The procedure is tested with full-scale data of an in-service container ship. Comparison between predictions and the actual measurements, implies a good agreement in general. This method can be an efficient way to improve decision support on board ships.

Uncertainties in ship-based estimation of waves and responses

Real time estimation of waves and ship responses using onboard measurements has been under investigation in recent years. This has been done using different methods, including parametric and non-parametric models. Since none of the methods are believed to be fully accurate, it is important to assign an uncertainty measure to the waves and responses that are being estimated. In this paper, a parametric model approach based on moments of responses is considered for wave estimation. A method based on linear error propagation is introduced to assess the uncertainty of wave estimations. The uncertainty of response calculation based on the estimated wave is also quantified.

Full Scale Measurements of the Hydro-Elastic Response of Large Container Ships for Decision Support

The overall topic of this thesis is decision support for operation of ships and several aspects are covered herein. However, the main focus is on the wave-induced hydro-elastic response of large container ships and its implications on the structural response.

The analyses are based mainly on full scale measurements from four container ships of 4,400 TEU, 8,600 TEU, 9,400 TEU and 14,000 TEU. Primarily, strains measured near the deck amidships are used. Furthermore, measurements of motions and the encountered sea state are available for one of the ships. The smallest ship is in operation on the North
Atlantic, while the three largest ships are operated on the Europe - Asia route.

In the design rules of the classification societies for container ships the minimum design sagging bending moment amidships is larger than the hogging bending moment. Due to their design (full midship section and slender bow and stern sections) and their normal cargo loading condition, container ships are typically operated in a still-water hogging condition (tension in deck and compression in the bottom structure). The wave-induced bending moment is added to the still-water bending moment, which, together with the smaller design hogging bending moment, generally makes the wave-induced hogging bending moment more critical than the sagging bending moment in the operation of container ships.

As container ships of today become larger, their natural vibration frequencies become lower and approach the typical encounter frequency with the waves. Together with the relatively high design speed and often pronounced bow flare this makes large container ship more sensitive to slamming and, consequently, the effects of wave-induced hull girder vibrations. From full scale strain measurements of individual, measured hull girder responses in the four container ships, the wave-induced hull girder vibrations are found to increase the vertical bending moment amidships by 100% or more. From the full scale measurements the amplification, due to the hull girder flexibility, is found to be largest for the 8,600 TEU and the 9,400 TEU ships, but, in addition to ship size, speed and bow flare angle are also believed to be important factors contributing to the hull girder vibrations.

The hull girder vibrational response is found to be dominated by the 2-node vertical bending mode. No torsional vibrations are found but torsion may, however, still be a concern for ultra large container ships. The damping of the 2-node vertical bending mode is estimated from full scale measurements for the four ships to 1.3-2.5% of the critical damping. No effect of ship size on the damping is identified.

In some cases the hogging bending moment is more amplified by the effect of the hull girder flexibility than the sagging bending moment. No general trend in the amplification of the response is found from the full scale measurements. In some cases, the rigid-body hogging bending moment, found from full scale measurements and model tests, is considerably larger than the corresponding sagging bending moment. Generally, the difference between the design sagging and hogging bending moments is not reflected in the full scale measurements considered here.

The extreme value of the vertical hogging bending moment, as estimated from full scale measurements, is investigated using the peak-over-threshold method for different periods. The tails of the peak distributions for the four different ships are found to be very different from case to case. The irregularity of the tail behaviour makes it difficult to determine an appropriate extreme value distribution for the hogging bending moment. The Gumbel distribution is believed to be the appropriate extreme value distribution, but it may be necessary to fit other types of extreme value distributions to the largest peaks.

From the full scale measurements it is difficult to assess the influence of operational parameters (ship speed, heading relative to the waves and wave height) on the extreme response because these data are not readily available in all cases. Model tests indicate that bow-quartering sea may induce larger structural loads on the ship than direct head sea and that the amplification of the response due to the hull girder flexibility is largest in bow-quartering waves. However, this fact is not necessarily reflected in the behaviour of ship masters who seemingly tend to prefer bow-quartering sea to head sea when encountering adverse weather.

Numerical design tools are widely used in ship design, but may not be able to fully capture the effect of the hull girder flexibility and are here found to significantly underestimate the effect compared to model tests and full scale measurements. Hence, full scale measurements from ships are highly valuable in the evaluation of existing designs and may reveal effects that cannot be assessed numerically.

For decision support, accurate knowledge of the encountered sea state parameters (wave height, period and relative wave direction) is crucial. One means to estimate the on-site sea state from an advancing ship is to use the wave buoy analogy, i.e. use the motions of the ship and the associated motion transfer functions to derive the sea state parameters. The method is promising but needs further refinement before it can be implemented in decision support systems on board ships.

Fatigue damage is estimated from full scale strain measurements from two of the container ships with focus on the assessment of the influence of the wave-induced high-frequency hull girder vibrations. In several cases, the high-frequency contribution to the fatigue damage is dominating the estimated fatigue damage. Spectral formulations for estimating fatigue damage from bi-modal processes are explored and found to yield results fairly similar to the outcome of classical fatigue damage estimation from rainfall counting. However, in a few cases higher fatigue damage rates were estimated from rainfall counting than from narrow-band approximations.

In summary and only considering larger container ships, the new and original contributions of the thesis are believed to be:

- From full scale measurements the hull girder vibrational response is generally found to be dominated by the 2-node vertical bending mode even when the ship is sailing in oblique seas.
- The vertical bending moment in hogging and sagging is amplified considerably by the effect of the hull girder flexibility.
and the wave-induced hull girder vibrations are found capable of increasing the vertical wave bending moment amidships by 100% or more.

- The vertical hogging bending moment can be as critical as the sagging bending moment in design.
- From comparison of models tests and numerical methods, it seems that the numerical methods are not capable of fully capturing the effect of hull girder flexibility seen in model tests.
- The peak-over-threshold method is found to be the most useful method for extreme value prediction of the vertical bending moment in combination with an appropriate asymptotic extreme value distribution.

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Publication: Research › Ph.D. thesis – Annual report year: 2014

Loads for use in the design of ships and offshore structures
The evaluation of structural responses is key element in the design of ships and offshore structures. Fundamental to this is the determination of the design loads to support the Rule requirements and for application in direct calculations. To date, the current design philosophy for the prediction of motions and wave-induced loads has been driven by empirical or first-principles calculation procedures based on well-proven applications such as ship motion prediction programs. In recent years, the software, engineering and computer technology available to predict the design loads imposed on ships and offshore structures has improved dramatically. Notwithstanding, with the stepwise increase in the size and structural complexity of ships and floating offshore installations and the advances in the framework of Rules and Standards it has become necessary to utilise the latest technologies to assess the design loads on new designs. Along the lines of the recommendations from the International Ship and Offshore Structures Committee (ISSC) I.2 on Loads this paper reviews some of the recent advances in the assessment of loads for ships and offshore structures with the aim to draw the overall technological landscape available for further understanding, validation and implementation by the academic and industrial communities. Particular emphasis is attributed on methodologies applicable for the prediction of environmental and operational loads from waves, wind, current, ice, slamming, sloshing and operational factors. Consideration is also given to deterministic and statistical load predictions based on model experiments, full-scale measurements and theoretical methods.

General information
State: Published
Organisations: Department of Mechanical Engineering, Fluid Mechanics, Coastal and Maritime Engineering, Lloyd's Register Group Ltd., INSEAN/CNR Maritime Research Centre, China Ship Scientific Research Center, Marine Technology Centre, Delft University of Technology, Osaka University, University of Zagreb, Technical University of Lisbon, Germanischer Lloyd SE, Istanbul Technical University, National University of Singapore, National Technical University of Athens, University of Strathclyde
Pages: 131–174
Publication date: 2014
Main Research Area: Technical/natural sciences
Parametric estimation in the wave buoy analogy - an elaborated approach based on energy considerations

An accurate estimation of the ocean wave directional spectrum at the location of an advancing ship is very useful for the ship master to improve operation and safety in a seaway. Research has been conducted to obtain sea state estimates by the Wave Buoy Analogy. The method deals with processing the ship’s wave-induced responses based on different statistical inferences including parametric and non-parametric approaches.

This paper considers a concept to improve the estimate obtained by the parametric method for sea state estimation. The idea is illustrated by an analysis made on full-scale response measurements carried out on a 9400 TEU container ship. The process of fitting a standard JONSWAP spectrum takes into account an analysis of residuals formed by the difference between measured and estimated amount of energy of the response(s).

A couple of motion responses and also bending moment are considered as the input of the estimation process. A comparison is made between the results and also with some in-hand outputs from other estimation sources, e.g., wave radar measurements and sea surface elevation by microwave sensors. The discussed and analyzed procedure could also lead to an automatic selection of response combinations for sea state estimation.

Reducing roll motion by passive free surface tanks

Roll stabilisation of motorised vessels plays an important part in reducing passenger discomfort and increasing safety and cargo capacity. Passive free surface tanks are considered a low-cost stabilising method, which is efficient at all speeds without increasing hull resistance.

In this study, a mathematical model for evaluating the performance of a passive free surface tank is established. This is done by coupling a roll model to a fluid flow model. As a numerical example, the seakeeping abilities of a container vessel are evaluated. The necessary methods for performing the simulation are presented and the design of a free surface tank is explained. The effects of the passive free surface tank are evaluated and a significant damping effect is observed, particularly in cases with resonant roll.
Study on Short-term Variability of Ship Responses in Waves
Short-term variability of ship responses is investigated from the view point of cross-spectrum analysis. In a steady state condition, it is well known that a certain length of sampled data are required for stable spectral analysis. However, the phase angle of the cross-spectra has not been discussed in detail. Using long stationary time histories, the transition of amplitudes and relative phase angles of the cross-spectra have been investigated by iterative analyzes with a few seconds of time shifting. In the results, the short-term variability of the relative phase angle was observed. This concludes that the variability influences the accuracy of the wave buoy analogy.

General information
State: Published
Organisations: Department of Mechanical Engineering, Fluid Mechanics, Coastal and Maritime Engineering, Tokyo University of Marine Science and Technology
Authors: Iseki, T. (Ekstern), Nielsen, U. D. (Intern)
Number of pages: 4
Publication date: 2014

The New Maritime Engineering Education at the Technical University of Denmark
Until 2010, the maritime engineering education at the Technical University of Denmark (DTU) followed the rather classical naval architecture approach with the main focus on marine hydrodynamics and strength of ship structures. The number of students was rather modest and constant. However, at that time the last major ship yard in Denmark was closing down and ship operation, together with ship design, became the main working area for the students after graduation. It was then decided to broaden the naval architecture education to a maritime engineering education taking marine logistics, management, transport optimization and engine system design into the curriculum. Furthermore, the concept of green shipping was introduced wherever relevant in teaching modules at DTU and two new maritime engineering courses were introduced: (1) Sailing practice in a merchant vessel or DTU’s research vessel (guided by the experience gained from Australian Maritime College in a similar course) and, (2) Green transportation dealing holistically with global ship transport. Furthermore, study trips to Asia visiting ship yards have been made possible by support from the various private funds. This new maritime engineering education has so far been very successful with the number of students increased by a factor of two and with very good job opportunities in the Danish maritime industry. A spin-off of this change is DTU's participation in a dual MSc degree engineering program: Nordic Master in Maritime Engineering where DTU is responsible for the study track Ship Operations. This change has also led to the creation of the centre Maritime DTU as a one-point entry for the industry and maritime authorities regarding R&D related maritime issues. The paper will discuss the process and the way ahead for further strengthening the interaction between maritime industries, ship owners, maritime authorities and universities dealing with maritime engineering in Denmark and internationally.

General information
State: Published
Organisations: Department of Mechanical Engineering, Fluid Mechanics, Coastal and Maritime Engineering
Authors: Jensen, J. J. (Intern), Andersen, I. M. V. (Intern), Nielsen, U. D. (Intern), Andersen, P. (Intern)
Pages: 353-359
Publication date: 2014
Comparisons of Means for Estimating Sea States from an Advancing Large Container Ship

The paper deals with sea state estimation from a container carrier (9,400 TEU) en-route. Knowledge of the on-site sea state is fundamental input to any kind of inservice decision support system that evaluates performance of, e.g., accelerations, fuel efficiency, and hull girder strength, related to ship-wave interactions in a seaway. In the paper, sea state estimates are produced by three means: the wave buoy analogy, relying on shipboard response measurements, a wave radar system, and a system providing the instantaneous wave height. The presented results show that for the given data, recorded on five different days of continuous operation, the agreement between the estimating means is reasonable; in terms of both absolute (mean) values and hourly trends of integrated sea state parameters.

Educating Maritime Engineers for a Globalised Industry

This paper deals with the analysis of recent full-scale strain measurements in the hull of a large container carrier covering several months of operation. The focus is on the real-time prediction accuracy of responses 5-15 seconds ahead of the measurements. Such results are less applicable in the operation of container carriers but are important in e.g. loading/unloading operations at sea or helicopter landings.

Evaluation of Response Prediction Procedures using Full Scale Measurements for a Container Ship

This paper deals with the analysis of recent full-scale strain measurements in the hull of a large container carrier covering several months of operation. The focus is on the real-time prediction accuracy of responses 5-15 seconds ahead of the measurements. Such results are less applicable in the operation of container carriers but are important in e.g. loading/unloading operations at sea or helicopter landings.
Three different procedures are discussed: Conditional processes with analytical estimates of the mean values and standard deviations, the autoregressive predictor method and a method based on superposition of sinusoidal components. The conditional processes do not need offline training and will be applied to measured time series in order to evaluate the accuracy of response predictions within the next 1-30 seconds. The number of measured points and the time distances between them are varied to determine the best solutions. A procedure based on 11 measured points spaced 1 sec, covering the last 10 sec of the instantaneous measured signal seems generally able to give fair predictions up to 5-10 sec ahead of the current time. The full-scale data is provided through the EU FP7 project Tools for Ultra Large Container Ships (TULCS) project no. 234146.

Study on a method for estimating fuel consumption in a seaway
On-board measurement of fuel consumption of a ship has been carried out in a relatively severe sea condition. In the full scale experiment, the ship traveled on several courses to investigate the change of fuel consumption relative to the encounter wave angle. The result shows that the wave direction has a great influence on the main engine horse power and fuel consumption, and also shows a possibility of fuel efficiency prediction. In order to develop an eco-friendly navigation support system, results of Bayesian wave estimation are applied to fuel efficiency prediction. The Bayesian method does not require wave measurements but needs only ship motion data as input and the method is suitable for on-site wave estimation.

Blind estimation of a ship's relative wave heading
This article proposes a method to estimate a ship's relative heading against the waves. The procedure relies purely on shipboard measurements of global responses such as motion components, accelerations and the bending moment amidships. There is no particular (mathematical) model connected to the estimate, and therefore it is called a 'blind estimate'. The approach is in this introductory study tested by analysing simulated data. The analysis reveals that it is possible to
estimate a ship’s relative heading on the basis of shipboard measurements only.

**Educating Maritime Engineers for a Globalised Industry - Bridging the Gap Between Industry and Universities**

In Denmark, the maritime engineering competences requested by the industry have changed in the past one to two decades. The typical naval architects do no longer find themselves working in the ship-building industry but rather in the industry of ship operators, consultancies, class societies, etc. This means that universities educating maritime engineers need to reflect the changes in the curricula for their maritime engineering students. Topics and issues regarding this matter have recently been addressed in a survey made in the Danish maritime industry. The survey concludes that the demand for maritime engineers in the industry is considerably larger than the output from the technical universities. Moreover, it sets forth a series of recommendations to the industry as well as to the universities to facilitate meeting the demand for maritime engineers in Denmark in the future. The recommendations are outlined together with work commenced at the Technical University of Denmark (DTU) to update the curricula for DTU’s maritime engineering students. Thus, DTU offers an education reflecting a large share of the recommendations in the curricula.

**Fremtidens maritime ingeniøruddannelse - Tiltag og visioner på Danmarks Tekniske Universitet**

**General information**
State: Published
Organisations: Department of Mechanical Engineering, Fluid Mechanics, Coastal and Maritime Engineering
Authors: Nielsen, U. D. (Intern), Andersen, I. M. V. (Intern)
Number of pages: 13
Publication date: 2012
Sea state estimation from an advancing ship – A comparative study using sea trial data

Onboard sea state estimation is relevant for evaluation of ship operations at sea. Means to obtain the sea state at a fixed position include a traditional wave rider buoy, where motion measurements of the buoy are processed to give the (directional) wave spectrum. The analogy between a ship and a buoy is clear, although the ship is moving with a forward speed and, in general, is characterised by a more complex underwater geometry. Thus, it is possible to obtain an estimate of the wave spectrum at the location of an advancing ship by processing its wave-induced responses similar to the situation of a traditional wave rider buoy. The paper studies the ‘wave buoy analogy’, and a large set of full-scale motion measurements is considered. It is shown that the wave buoy analogy gives fairly accurate estimates of integrated sea state parameters when compared to corresponding estimates from real wave rider buoys. The complete distribution of wave energy is also compared, however, with poorer agreement. Finally, it is shown that the wave buoy analogy, for the studied data, provides, on average, slightly better sea state estimates than a wave radar system.
**General information**

State: Published  
Organisations: Department of Mechanical Engineering, Fluid Mechanics, Coastal and Maritime Engineering  
Authors: Nielsen, U. D. (Intern), Andersen, I. M. V. (Intern)  
Number of pages: 23  
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**Publication information**

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Publisher: DTU Mechanical Engineering  
Main Research Area: Technical/natural sciences  
Electronic versions:  
WaveEstim_SkibstekniskSelskab.pdf  
Source: dtu  
Source-ID: u::4039  
Publication: Communication › Sound/Visual production (digital) – Annual report year: 2012

**The Maritime Engineering Education: meeting industry demands**

This article describes the outcome of a survey initiated by the Danish Maritime Fund (DMF). The survey resulted in a report that describes the engineering competencies requested by the Danish maritime industry. This is of interest since the desired competencies have changed in the past one to two decades, where Denmark no longer has a considerable ship-building industry. Furthermore, the DMF initiated report concludes that the demand for maritime engineers in the industry is larger than the output. The report sets forth a series of recommendations to the industry as well as the universities to enable meeting the demand for maritime engineers in Denmark. The recommendations are outlined together with the work commenced at the Technical University of Denmark (DTU) and the University of Southern Denmark (SDU) to follow up on the recommendations in the report.

**General information**

State: Published  
Organisations: Department of Mechanical Engineering, Fluid Mechanics, Coastal and Maritime Engineering, University of Southern Denmark
Towards fault-tolerant decision support systems for ship operator guidance

Fault detection and isolation are very important elements in the design of fault-tolerant decision support systems for ship operator guidance. This study outlines remedies that can be applied for fault diagnosis, when the ship responses are assumed to be linear in the wave excitation. A novel numerical procedure is described for the calculation of residuals using the ship’s transfer functions which correlate the wave excitation and the ship responses. As tests, multiplicative faults have artificially been imposed to full-scale motion measurements and it is shown that the developed model is able to detect and isolate all faults.

General information
State: Published
Organisations: Department of Mechanical Engineering, Fluid Mechanics, Coastal and Maritime Engineering, A. P. Møller-Mærsk
Authors: Nielsen, U. D. (Intern), Lajic, Z. (Ekstern), Jensen, J. J. (Intern)
Pages: 1-14
Publication date: 2012
Main Research Area: Technical/natural sciences
A novel approach for navigational guidance of ships using onboard monitoring systems

A novel approach and conceptual ideas are outlined for risk-based navigational guidance of ships using decision support systems in combination with onboard, in-service monitoring systems. The guidance has as the main objective to advise on speed and/or course changes; in particular with focus on ship operations in rough weather. It is strived for to make use of a probabilistic framework considering the mathematical procedures that the guidance relies upon. The paper presents a novel concept which has the possibility to increase the reliability of the provided guidance, although information about on-site sea state parameters not necessarily is in complete agreement with the unknown and true wave parameters, normay the hydrodynamical models of the vessel give a perfect quantitatively description of the vessel in waves. The paper includes an analysis of full-scale motion measurements and the proposed concept for navigational guidance gives promising results.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Nielsen, U. D. (Intern), Jensen, J. J. (Intern)
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Publication date: 2011
Main Research Area: Technical/natural sciences

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Journal: Ocean Engineering
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Web of Science (2017): Indexed yes
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Scopus rating (2016): CiteScore 2.46 SJR 1.315 SNIP 2.014
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.172 SNIP 1.989 CiteScore 2.19
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.252 SNIP 2.323 CiteScore 2.11
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.178 SNIP 2.773 CiteScore 2.2
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.206 SNIP 2.445 CiteScore 1.71
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.055 SNIP 2.528 CiteScore 1.85
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.153 SNIP 2.207
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.063 SNIP 1.975
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.935 SNIP 1.673
Scopus rating (2007): SJR 0.941 SNIP 1.912
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.887 SNIP 1.773
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.524 SNIP 1.36
Scopus rating (2004): SJR 0.715 SNIP 1.338
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.729 SNIP 1.287
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.886 SNIP 1.149
Scopus rating (2001): SJR 0.599 SNIP 0.983
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.55 SNIP 1.215
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 0.467 SNIP 0.648

Original language: English
Risk-based approaches, Uncertainty modelling, Gaussian and non-Gaussian processes, Navigational guidance of ships, Decision support systems for safety, Wave estimation

Electronic versions:
NavigationGuidance.pdf
DOIs:
10.1016/j.oceaneng.2010.11.024

Bibliographical note
A Study on Parametric Wave Estimation Based on Measured Ship Motions
The paper studies parametric wave estimation based on the ‘wave buoy analogy’, and data and results obtained from the training ship Shioji-maru are compared with estimates of the sea states obtained from other measurements and observations. Furthermore, the estimating characteristics of the parametric model are discussed by considering the results of a similar estimation concept based on Bayesian modelling. The purpose of the latter comparison is not to favour the one estimation approach to the other but rather to highlight some of the advantages and disadvantages of the two approaches.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, Tokyo University of Marine Science and Technology
Authors: Nielsen, U. D. (Intern), Iseki, T. (Ekstern)
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Main Research Area: Technical/natural sciences

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BFI (2016): BFI-level 1
BFI (2015): BFI-level 1
BFI (2014): BFI-level 1
BFI (2013): BFI-level 1
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
BFI (2009): BFI-level 1
BFI (2008): BFI-level 1
Original language: English
Onboard wave estimation, Parameterised wave spectra, Seakeeping, Nonlinear optimisation, Full-scale ship motion measurements
Electronic versions:
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Source: orbit
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Publication: Research - peer-review › Journal article – Annual report year: 2012


General information
State: Published
Organisations: Department of Mechanical Engineering, Fluid Mechanics, Coastal and Maritime Engineering, OSK-ShipTech, Akademiet for de Tekniske Videnskaber, University of Southern Denmark, Søfartsstyrelsen, American Bureau of Shipping, A. P. Møller-Mærsk, MAN Diesel & Turbo SE
Authors: Simonsen, B. C. (Ekstern), Hansen, A. Ø. (Ekstern), Røge, E. F. (Ekstern), Andersen, I. M. V. (Intern), Lützen, M. (Ekstern), Bech, M. S. (Ekstern), Tang-Jensen, P. (Ekstern), Knudsen, T. S. (Ekstern), Nielsen, U. D. (Intern)
Number of pages: 9
Publication date: 2011
Onboard monitoring of fatigue damage rates - Decision support and sea state estimation

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, Yokohama National University
Authors: Nielsen, U. D. (Intern), Jensen, J. J. (Intern), Pedersen, P. T. (Intern), Ito, Y. (Ekstern)
Publication date: 2011

Onboard monitoring of fatigue damage rates in the hull girder
Most new advanced ships have extensive data collection systems to be used for continuous monitoring of engine and hull performance, for voyage performance evaluation etc. Such systems could be expanded to include also procedures for stress monitoring and for decision support, where the most critical wave-induced ship extreme responses and fatigue damage accumulation can be estimated for hypothetical changes in ship course and speed in the automatically estimated wave environment. The aim of this paper is to outline a calculation procedure for fatigue damage rate prediction in hull girders taking into account whipping stresses. It is conceptually shown how such a method, which integrates onboard estimation of sea states, can be used to deduce decision support with respect to the accumulated fatigue damage in the hull girder. The paper firstly presents a set of measured full-scale wave-induced stress ranges in a container ship, where the associated fatigue damage rates calculated from a combination of the rain-flow counting method and the Palmgren-Miner damage rule are compared with damage predictions obtained from a computationally much faster frequency fatigue analysis using a spectral method. This analysis verifies the applied multi-modal spectral analysis procedure for fatigue estimation for cases where hull girder flexibility plays a role. To obtain an automated prediction method for the fatigue damage rates it is in the second part of the paper shown how a combination of the full-scale onboard acceleration and stress measurements can be used to calculate sea state parameters. These calculated environmental data are verified by a comparison to hindcast data. In the third part of the paper the full-scale fatigue stress ranges are compared to results from an analytical design oriented calculation procedure for flexible ship hulls in short-term estimated sea states. Altogether, it is conceptually shown that by a combination of the onboard estimated sea state parameters with the described analytical fatigue damage prediction procedure a method can be established for real-time onboard decision support which includes estimates of fatigue damage rates.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, Yokohama National University
Authors: Nielsen, U. D. (Intern), Jensen, J. J. (Intern), Pedersen, P. T. (Intern), Ito, Y. (Ekstern)
Pages: 182-206
Publication date: 2011
Main Research Area: Technical/natural sciences
Onboard sea state estimation based on measured ship motions

It is possible to obtain estimates of the sea state at the specific position of an advancing vessel by processing measurements of the vessel's wave-induced responses. The analogy to a wave rider buoy is clear, although the situation of an advancing ship is more complex due to forward speed. The paper studies the 'wave buoy analogy', and a large set of full-scale motion measurements is considered. It is shown that the wave buoy analogy gives fairly accurate estimates of sea state parameters when compared to estimates from real wave rider buoys.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, Defence Research and Development Canada
Authors: Nielsen, U. D. (Intern), Stredulinsky, D. C. (Ekster)
Publication date: 2011

Host publication information
Title of host publication: Proceedings of the 12th International Ship Stability Workshop
Main Research Area: Technical/natural sciences
Avancing ship, Sea state estimation, Decision support systems, Motion measurements
Electronic versions:
ISSW_2011_UDN.pdf

Bibliographical note
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Source: orbit
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Publication: Research - peer-review > Article in proceedings – Annual report year: 2011

Fault-Tolerant Onboard Monitoring and Decision Support Systems

The purpose of this research project is to improve current onboard decision support systems. Special focus is on the onboard prediction of the instantaneous sea state. In this project a new approach to increasing the overall reliability of a monitoring and decision support system has been established. The basic idea is to convert the given system into a fault-tolerant system and to improve multi-sensor data fusion for the particular system. The background of the project is the SeaSense system, which has been installed on several container ships and navy vessels. The SeaSense system provides a crude and simple estimation of the actual sea state (Hs and Tz), information about the longitudinal hull girder loading, seakeeping performance of the ship, and decision support on how to operate the ship within acceptable limits. The system is able to identify critical forthcoming events and to give advice regarding speed and course changes to decrease the wave-induced loads. The SeaSense system is based on the combined use of a mathematical model and measurements from a set of sensors. The overall dependability of a shipboard monitoring and decision support system such as the SeaSense system can be improved using fault-tolerant techniques (Fault Diagnosis and System Re-design) and a Sensor Fusion Quality (SFQ) test. Fault diagnosis means to detect the presence of faults in the system. In case sea state estimation is conducted by a ship-wave buoy analogy the best solution is achieved when a set of three different ship responses are used. Faulty signals should be discarded from the procedure for sea state estimation if it is possible, if not the fault should be estimated. The fault diagnosis can be divided into three steps: Fault detection, fault isolation and fault estimation. Fault detection means to decide whether or not a fault has occurred. This step determines the time at which the system is subjected to the given fault. Fault isolation will find in which component a fault has occurred. This step determines the location of the fault. Fault estimation provides an estimate of magnitude of a fault. A supervisory function determines the severity of the fault once its origin has been isolated and its magnitude estimated. Fault-tolerant Sensor Fusion means that the monitoring and decision support system can accommodate faults so that the overall system continues to satisfy its goal and on the other hand in the absence of a fault, the system should be able to provide the most accurate information using the SFQ test.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, Automation and Control, Department of Electrical Engineering
Authors: Lajic, Z. (Intern), Nielsen, U. D. (Intern), Jensen, J. J. (Intern), Blanke, M. (Intern)
Number of pages: 179
Publication date: Oct 2010

Publication information
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Calculation of mean outcrossing rates of non-Gaussian processes with stochastic input parameters - Reliability of containers stowed on ships in severe sea

Mean outcrossing rates can be used as a basis for decision support for ships in severe sea. The article describes a procedure for calculating the mean outcrossing rate of non-Gaussian processes with stochastic input parameters. The procedure is based on the first-order reliability method (FORM) and stochastic parameters are incorporated by carrying out a number of FORM calculations corresponding to combinations of specific values of the stochastic parameters. Subsequently, the individual FORM calculation is weighted according to the joint probability with which the specific combination of parameter values is expected to occur, and the final result, the mean outcrossing rate, is obtained by summation. The derived procedure is illustrated by an example considering the forces in containers stowed on ships and, in particular, results are presented for the so-called racking failure in the containers. The results of the procedure are compared with brute force simulations obtained by Monte Carlo simulation (MCS) and good agreement is observed. Importantly, the procedure requires significantly less CPU time compared to MCS to produce mean outcrossing rates.

General information
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Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Nielsen, U. D. (Intern)
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Main Research Area: Technical/natural sciences

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Volume: 25
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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 0.834 SNIP 1.632 CiteScore 1.9
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.313 SNIP 1.967 CiteScore 2.1
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.65 SNIP 1.958 CiteScore 2.08
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.543 SNIP 2.054 CiteScore 2.6
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.318 SNIP 1.998 CiteScore 1.62
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.817 SNIP 2.446 CiteScore 2.04
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.141 SNIP 1.953
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.451 SNIP 2.024
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.5 SNIP 2.317
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.625 SNIP 2.664
Scopus rating (2006): SJR 1.106 SNIP 1.569
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.077 SNIP 1.705
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.906 SNIP 1.322
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 1.1 SNIP 1.045
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 1.058 SNIP 1.413
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.475 SNIP 0.805
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.459 SNIP 1.312
Scopus rating (1999): SJR 0.54 SNIP 1.231
Original language: English
Decision support systems for ships, Monte Carlo simulation, Mean outcrossing rate, Non-Gaussian processes, Racking failure, Stowed containers, First-order reliability method (FORM)
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Source-ID: 263425
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Estimation of fatigue damage from full-scale measurements of hull girder stresses

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, Yokohama National University
Authors: Ito, Y. (Ekstern), Nielsen, U. D. (Intern), Jensen, J. J. (Intern)
Publication date: 2010

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Source: orbit
Source-ID: 267704
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010

Estimation of sea state parameters from measured ship responses: The Bayesian approach with fixed hyperparameters

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, Tokyo University of Marine Science and Technology

Fault Isolation and quality assessment for shipboard monitoring

In this paper a new approach for increasing the overall reliability of a monitoring and decision support system will be explained. The focus is on systems used for ship operator guidance with respect to, say, speed and heading. The basic idea is to convert the given system into a fault tolerant system and to improve multi-sensor data fusion for the particular system. Fault isolation is an important part of the fault tolerant design for in-service monitoring and decision support systems for ships. In the paper, a virtual example of fault isolation will be presented. Several possible faults will be simulated and isolated using residuals and the generalized likelihood ratio (GLR) algorithm. It will be demonstrated that the approach can be used to increase accuracy of sea state estimations employing sensor fusion quality test.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, Automation and Control, Department of Electrical Engineering
Authors: Lajic, Z. (Intern), Nielsen, U. D. (Intern), Blanke, M. (Intern)
Number of pages: 8
Pages: OMAE2010-20280
Publication date: 2010

Fault Isolation for Shipboard Decision Support

Fault detection and fault isolation for in-service decision support systems for marine surface vehicles will be presented in this paper. The stochastic wave elevation and the associated ship responses are modeled in the frequency domain. The paper takes as an example fault isolation of a containership on which a decision support system has been installed and it will be demonstrated that all the faults can be isolated. The paper shows how a shipboard decision support system could become highly reliable and comprise built-in supervision of the quality of the sensor signals that are crucial to the quality of decisions given to navigators.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, Automation and Control, Department of Electrical Engineering
Authors: Lajic, Z. (Intern), Blanke, M. (Intern), Nielsen, U. D. (Intern)
Publication date: 2010

Host publication information
Title of host publication: 29th International Conference on Ocean, Offshore and Arctic Engineering (OMAE 2010)
Place of publication: Shanghai, China
Publisher: American Society of Mechanical Engineers
Edition: 29
ISBN (Print): 978-0-7918-3873-0
Main Research Area: Technical/natural sciences
Conference: 29th International Conference on Ocean, Offshore and Arctic Engineering, Shanghai, China, 06/06/2010 - 06/06/2010
Onboard systems, Fault Isolation, Sensor Fusion Quality (SFQ) test
Electronic versions:
OMAE2010-20280.pdf
Links:
hhttp://www.skk.mek.dtu.dk
Source: orbit
Source-ID: 267148
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010
Lecture notes in ship operations

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Nielsen, U. D. (Intern)
Publication date: 2010

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 253393
Publication: Education › Compendium/lecture notes – Annual report year: 2010

Navigational guidance based on combined use of sea state estimation and response measurements

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, Defence Research and Development Canada
Authors: Nielsen, U. D. (Intern), Stredulinsky, D. (Ekstern)
Publication date: 2010

Host publication information
Title of host publication: Proc. of 11th International Symposium on Practical Design of Ships and Other Floating Structures
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 267703
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010

The wave buoy analogy: Analysis of synthetic data by Bayesian modelling

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Nielsen, U. D. (Intern)
Publication date: 2010

Host publication information
Title of host publication: Proc. of 29th International Conference on Ocean, Offshore and Arctic Engineering
Main Research Area: Technical/natural sciences
Conference: 29th International Conference on Ocean, Offshore and Arctic Engineering, Shanghai, China, 06/06/2010 - 06/06/2010
Source: orbit
Source-ID: 267701
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010

A step towards risk-based decision support for ships - Evaluation of limit states using parallel system analysis

Onboard decision support systems (DSS) are used to increase the operational safety of ships. Ideally, DSS can estimate future ship responses within a time scale of the order of 1–3 h taking into account speed and course changes, assuming stationary sea states. In principle, the calculations depend on a large amount of operational and environmental parameters, which will be known only in the statistical sense. The present paper suggests a procedure to incorporate random variables and associated uncertainties in the calculations of the outcrossing rates that are the basis for riskbased
DSS. The procedure is based on parallel system analysis, and the paper derives and describes the main ideas. The concept is illustrated by an example, where the limit state of a non-linear ship response is considered. The results from the parallel system analysis are in agreement with corresponding Monte Carlo simulations. However, the computational speed of the parallel system analysis proved slower than expected.
Fault Detection for Shipboard Monitoring and Decision Support Systems

In this paper a basic idea of a fault-tolerant monitoring and decision support system will be explained. Fault detection is an important part of the fault-tolerant design for in-service monitoring and decision support systems for ships. In the paper, a virtual example of fault detection will be presented for a containership with a real decision support system onboard. All possible faults can be simulated and detected using residuals and the generalized likelihood ratio (GLR) algorithm.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Lajic, Z. (Intern), Nielsen, U. D. (Intern)
Number of pages: 8
Pages: OMAE2009-79367
Publication date: 2009

Fault Detection for Shipboard Monitoring – Volterra Kernel and Hammerstein Model Approaches

In this paper nonlinear fault detection for in-service monitoring and decision support systems for ships will be presented. The ship is described as a nonlinear system, and the stochastic wave elevation and the associated ship responses are conveniently modelled in frequency domain. The transformation from time domain to frequency domain has been conducted by use of Volterra theory. The paper takes as an example fault detection of a containership on which a decision support system has been installed.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, Automation and Control, Department of Electrical Engineering
Numerical Simulations of the Rolling of a Ship in a Stochastic Sea - Evaluations by use of MCS and FORM

Calculating Outcrossing Rates used in Decision Support Systems for Ships

Introducing two hyperparameters in Bayesian estimation of wave spectra
only one hyperparameter has been used to control the amount of smoothing applied in both the frequency and directional ranges. From numerical simulations of stochastic response measurements, it is shown that the optimal hyperparameters, determined by use of ABIC (a Bayesian Information Criterion), correspond to the best estimate of the wave spectrum, which is not always the case when only one hyperparameter is included in the Bayesian modelling. The paper includes also an analysis of full-scale motion measurements where wave spectra estimated by the Bayesian modelling are compared with results from ocean surface measurements by satellite and from a wave radar. The agreement is found to be reasonable.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Nielsen, U. D. (Intern)
Pages: 84-94
Publication date: 2008
Main Research Area: Technical/natural sciences

Publication information
Journal: Probabilistic Engineering Mechanics
Volume: 23
Issue number: 1
ISSN (Print): 0266-8920
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 0.834 SNIP 1.632 CiteScore 1.9
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.313 SNIP 1.967 CiteScore 2.1
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.65 SNIP 1.958 CiteScore 2.08
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.543 SNIP 2.054 CiteScore 2.6
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.318 SNIP 1.998 CiteScore 1.62
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.817 SNIP 2.446 CiteScore 2.04
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.141 SNIP 1.953
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.451 SNIP 2.024
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.5 SNIP 2.317
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.625 SNIP 2.664
Scopus rating (2006): SJR 1.106 SNIP 1.569
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.077 SNIP 1.705
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.906 SNIP 1.322
The wave buoy analogy - estimating high-frequency wave excitations

The paper deals with the wave buoy analogy where a ship is considered as a wave buoy, so that measured ship responses are used as a basis to estimate wave spectra and associated sea state parameters. The study presented follows up on a previous paper, Nielsen [Nielsen UD. Response-based estimation of sea state parameters — influence of filtering. Ocean Engineering 2007;34:1797–810.], where time series of ship responses were generated from a known wave spectrum for the purpose of the inverse process — the estimation of the underlying wave excitations. Similar response generations and vice versa processes are carried out in the present paper; however with one of the responses being the relative motion which is a type of response that is sensitive to high-frequency excitations. Based on the present study it is shown that by including the relative motion, the frequency-wise energy distribution can be estimated reasonably well, even considering high-frequency wave components of a wind sea wave spectrum.
Bayesian Estimation of Wave Spectra – Proper Formulation of ABIC

It is possible to estimate on-site wave spectra using measured ship responses applied to Bayesian Modelling based on two prior information: the wave spectrum must be smooth both directional-wise and frequency-wise. This paper introduces two hyperparameters into Bayesian Modelling and, hence, a proper formulation of ABIC (a Bayesian Information Criterion) is given, in contrast to the improper formulation given of ABIC when only one hyperparameter is included. From a numerical example, the paper illustrates that the optimum pair of hyperparameters, determined by use of ABIC, corresponds to the best estimate of the wave spectrum. In addition, full-scale motion measurements are analysed and the estimated wave spectra are compared with estimations made by wave radar measurements and satellite measurements. The agreement is reasonable.
Response-Based Estimation of Sea State Parameters

Reliable estimation of the on-site sea state parameters is essential to decision support systems for safe navigation of ships. The sea state parameters can be estimated by Bayesian Modelling which uses complex-valued frequency response functions (FRF) to estimate the wave spectrum on the basis of measured ship responses. It is therefore interesting to investigate how the filtering aspect, introduced by FRF, affects the final outcome of the estimation procedures. The paper contains a study based on numerical generated time series, and the study shows that filtering has an influence on the estimations, since high frequency components of the wave excitations are not estimated as accurately as lower frequency components. Moreover, the paper investigates how the final outcome of the Bayesian Modelling is influenced by the accuracy of the FRF. Thus, full-scale data is analysed by use of FRF calculated by a 3-D time domain code and by closed-form (analytical) expressions, respectively. Based on comparisons with wave radar measurements and satellite measurements it is seen that the wave estimations based on closedform expressions exhibit a reasonable energy content, but the distribution of energy appears to be incorrect.

Response-based estimation of sea state parameters - Influence of filtering

Reliable estimation of the on-site sea state parameters is essential to decision support systems for safe navigation of ships. The wave spectrum can be estimated from procedures based on measured ship responses. The paper deals with two procedures—Bayesian Modelling and Parametric Modelling—which both use complex-valued frequency response functions (FRF) to estimate the wave spectrum. It is therefore interesting to investigate how the filtering aspect, introduced by FRF, affects the final outcome of the estimation procedures. In order to do this, extensive numerical simulations—with known wave parameters—are carried out for a large container vessel. The study shows that filtering has an influence on the estimations, since high-frequency components of the wave excitations are not estimated as accurately as lower frequency components.
Comparisons of Methods for Estimation of On-site Directional Wave Spectra

Estimations of On-site Directional Wave Spectra from Measured Ship Responses

In general, two main concepts can be applied to estimate the on-site directional wave spectrum on the basis of ship response measurements: 1) a parametric method which assumes the wave spectrum to be composed by parameterised wave spectra, or 2) a non-parametric method where the directional wave spectrum is found directly as the values in a completely discretised frequency-directional domain without a priori assumptions on the spectrum. The paper outlines the theory of these two concepts, and it is shown how to deal with the speed-of-advance problem for operating ships. In addition, the methods include an equivalence of energy in the governing equations and, as regards the parametric concept, a frequency dependent spreading of the waves is introduced. The paper includes an extensive analysis of full-scale measurements for which the directional wave spectra are estimated by the two ship response based methods. Hence, comparisons are made between these estimates and, moreover, the agreement with the corresponding directional wave spectra produced by the wave radar system WAVEX is studied. The agreement between the two methods is reasonable, as well as the agreement between the results of these methods and those of WAVEX. It is difficult to propose one of the ship response based methods in favour of the other, since they perform equally well.

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Nielsen, U. D. (Intern)
Pages: 346-357
Publication date: 2006

Host publication information
Main Research Area: Technical/natural sciences
Conference: Pacific'06, 05/11/1829
Source: orbit
Source-ID: 183388
Publication: Research - peer-review › Article in proceedings – Annual report year: 2006

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering
Authors: Nielsen, U. D. (Intern)
Pages: 33-69
Publication date: 2006
Main Research Area: Technical/natural sciences

Publication information
Journal: Marine Structures
Volume: 19
Issue number: 1
ISSN (Print): 0951-8339
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.49 SJR 1.655 SNIP 2.636
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.618 SNIP 2.602 CiteScore 2.77
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.431 SNIP 3.026 CiteScore 2.18
SeaSense - Real-time Onboard Decision Support

General information
State: Published
Organisations: Coastal, Maritime and Structural Engineering, Department of Mechanical Engineering, FORCE Institute
Authors: Nielsen, J. K. (Ekstern), Pedersen, N. H. (Ekstern), Michelsen, J. (Ekstern), Nielsen, U. D. (Intern), Baatrup, J. (Intern), Jensen, J. J. (Intern), Petersen, E. S. (Ekstern)
Publication date: 2006

Host publication information
Title of host publication: World Maritime Technology Conference
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 183904
Publication: Research - peer-review › Article in proceedings – Annual report year: 2006
Ride Control Systems - Reduced Motions on the Cost of Increased Sectional Forces
Implementation of passive and active ride control systems into both linear frequency and non-linear time domain strip theories is described. The ride control systems considered can consist of T-foils, fins or a combination of these. These appendages are taken into account by considering the lift forces induced by the flow around them. In the frequency domain the appendages are included simply by modifying the equations of motion. This is done without introducing any non-linearities and hence the application of linear statistics is still valid. In the time domain the appendages are included by adding the lift forces to the exciting forces in the equations of motion. One of the advantages in the time domain is that the angle of attack can be limited easily, as is often the case in real full scale ride control systems. This way cavitation and finally stalling can be avoided. In the frequency domain limits on the angle of attack cannot be set. Since the lift coefficient is treated linearly the calculated lift force is severely overestimated in rough sea. Secondly the effect of including ride control systems in the calculations is demonstrated through comparisons of RMS values and of response operators for the ships main responses, e.g. motions, accelerations and sectional forces. Especially emphasis is given to the effect on the sectional forces, as preliminary results indicate that these in some cases are increased considerably by the T-foil ride control systems. Finally, the effect of the ride control systems on the hydro-elastic behaviour of the hull girder is investigated with the non-linear time domain strip theory code.
Host publication information
Title of host publication: Proceedings of 7th International Conference on FAST
Volume: 3, Session E
Place of publication: Naples, Italy
Publisher: Department of Naval Architecture and Marine Engineering and Institute of Navigation
Main Research Area: Technical/natural sciences
Conference: 7th International Conference on Fast Sea Transportation (FAST 2003), Ischia, Italy, 07/10/2003 - 07/10/2003
Source: orbit
Source-ID: 25709
Publication: Research - peer-review › Article in proceedings – Annual report year: 2003

Projects:

Reconfigurable Modular Robotic System for Aquatic Environment
Department of Electrical Engineering
Automation and Control
Centre for Playware
National Institute of Aquatic Resources
Section for Oceans and Arctic
Department of Mechanical Engineering
Engineering Design and Product Development
Fluid Mechanics, Coastal and Maritime Engineering
Period: 01/02/2016 → 31/01/2018
Number of participants: 6
Acronym: REMORA
Project participant:
Christensen, David Johan (Intern)
Mariani, Patrizio (Intern)
Visser, Andre (Intern)
Özkil, Ali Gürçan (Intern)
Nielsen, Ulrik Dam (Intern)
Project Manager, academic:
Galeazzi, Roberto (Intern)

Development of a decision support system for ships based on continuous measurements
Department of Mechanical Engineering
Period: 01/08/2014 → 30/07/2018
Number of participants: 4
Phd Student:
Choi, Ju Hyuck (Intern)
Supervisor:
Andersen, Ingrid Marie Vincent (Intern)
Jensen, Jørgen Juncher (Intern)
Main Supervisor:
Nielsen, Ulrik Dam (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Privatist
Project: PhD

Operation of Ultra Large Container Ships
Department of Mechanical Engineering
Period: 15/03/2013 → 04/07/2016
Number of participants: 6
Phd Student:
Montazeri, Najmeh (Intern)
Supervisor:
Jensen, Jørgen Juncher (Intern)
Main Supervisor:
Nielsen, Ulrik Dam (Intern)
Examiner:
Bingham, Harry B. (Intern)
Dietz, Jesper Skjoldager (Intern)
Iseki, Toshio (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut, samfinansiering

Relations
Publications:
Estimation of waves and ship responses using onboard measurements
Project: PhD

Integreatet beslutningsstøttesystem for brug om bord i skibe

Department of Mechanical Engineering
Period: 01/11/2010 → 29/09/2014
Number of participants: 7
Phd Student:
Andersen, Ingrid Marie Vincent (Intern)
Supervisor:
Nielsen, Ulrik Dam (Intern)
Sinding, Peter (Intern)
Main Supervisor:
Jensen, Jørgen Juncher (Intern)
Examiner:
Bingham, Harry B. (Intern)
Dietz, Jesper Skjoldager (Intern)
Bingham, Harry B. (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: 1/3 FUU, 1/3 inst 1/3 Andet

Relations
Publications:
Full Scale Measurements of the Hydro-Elastic Response of Large Container Ships for Decision Support
Project: PhD

Onboard Decision Support Systems for Optimal Operation

Department of Mechanical Engineering
Period: 01/09/2007 → 02/02/2011
Number of participants: 6
Phd Student:
Lajic, Zoran (Intern)
Supervisor:
Jensen, Jørgen Juncher (Intern)
Main Supervisor:
Nielsen, Ulrik Dam (Intern)
Examiner:
Pedersen, Preben Terndrup (Intern)
Petersen, Jakob Buus (Ekstern)
Sørensen, Asgeir Johan (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Eksternt finansieret virksomhed
Project: PhD

**Vessel Performance Control**
Department of Mechanical Engineering
Period: 01/03/2007 → 19/03/2015
Number of participants: 7
Phd Student:
Pedersen, Benjamin Pjedsted (Intern)

Supervisor:
Larsen, Jan (Intern)
Sinding, Peter (Intern)
Main Supervisor:
Andersen, Poul (Intern)
Examiner:
Nielsen, Ulrik Dam (Intern)
Ringsberg, Jonas W. (Ekstern)
Steen, Sverre (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: ErhvervsPhD-ordningen VTU
Project: PhD

**Monitorering og beslutningsstøtte for skibes sødygtighed**
Department of Mechanical Engineering
Period: 01/03/2002 → 28/09/2005
Number of participants: 6
Phd Student:
Nielsen, Ulrik Dam (Intern)

Supervisor:
Baatrup, Jan (Intern)
Main Supervisor:
Jensen, Jørgen Juncher (Intern)
Examiner:
Bingham, Harry B. (Intern)
Cerup-Simonsen, Bo (Intern)
Myrhaug, Dag (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Offentlig finansiering
Project: PhD

**Activities:**

*Response prediction of vessel motions and sea state estimation from ships*
Period: 17 Nov 2017
Ulrik Dam Nielsen (Guest lecturer)

Department of Mechanical Engineering
Fluid Mechanics, Coastal and Maritime Engineering
Description
Seminar at University of California - Berkeley @ Ocean Engineering.
Documents:
Response prediction and SSE (UCB Nov. 2017)

Related external organisation
University of California at Berkeley
United States
Activity: Talks and presentations › Conference presentations

Shipboard sea state estimation based on wave-induced response measurements
Period: 26 Sep 2017
Ulrik Dam Nielsen (Guest lecturer)
Department of Mechanical Engineering
Fluid Mechanics, Coastal and Maritime Engineering
Degree of recognition: International
Documents:
WaveEstim and DSS (MIT Sep. 2017)

Related external organisation
Massachusetts Institute of Technology
Cambridge, United States
Activity: Talks and presentations › Conference presentations

New Concepts for Shipboard Sea State Estimation
Period: 1 Mar 2016
Ulrik Dam Nielsen (Speaker)
Department of Mechanical Engineering
Fluid Mechanics, Coastal and Maritime Engineering

Description
Seminar talk/presentation given at University of California, Santa Barbara, USA.
Documents:
SeaStateEstimation_UCSB

Related external organisation
Unknown external organisation
Activity: Talks and presentations › Conference presentations

Maritime Engineering Education (at DTU): What are the challenges?
Period: 9 Oct 2015
Ulrik Dam Nielsen (Lecturer)
Department of Mechanical Engineering
Fluid Mechanics, Coastal and Maritime Engineering
Documents:
Maritime education - What are the challenges

Related event
Danish Maritime Days: ATV Seminar
05/10/2015 → 09/10/2015
Denmark
Activity: Talks and presentations › Conference presentations
Response-based sea state estimation for onboard DSS - Safe and Efficient Marine Operations
Period: 13 Nov 2014
Ulrik Dam Nielsen (Invited speaker)
Department of Mechanical Engineering
Fluid Mechanics, Coastal and Maritime Engineering

Description
Guest lecture given at NTNU, Trondheim, Norway, November, 2014.
Documents:
WaveEstim and DSS (AMOS Workshop)

Related external organisation
Unknown external organisation
Activity: Talks and presentations › Conference presentations