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### 6 Lagrangian Modelling of an Underwater Wave Glider

By **Andrea Caiti, Vincenzo Calabró, Sergio Grammatico, Andrea Munafó & Mirko Stifani**

This paper introduces a control-oriented modelling approach for a hybrid autonomous underwater vehicle, the Underwater Wave Glider. The vehicle can accomplish both surface and underwater tasks by changing its shape: it can operate as a wave glider at the sea surface, exploiting wave and solar energy to recharge the onboard batteries, and switch to the typical torpedo-shaped configuration to operate as a self-propelled autonomous underwater vehicle. The vehicle dynamics is modelled using a novel Lagrangian approach. Simulation results are provided.

### 14 Optimal Hull-Form Design Subject to Epistemic Uncertainty

By **Matteo Diez & Daniele Peri**

The paper presents an application of ship design optimisation subject to epistemic uncertainty. Generally, uncertainty that results from intrinsic variability (e.g. stochastic environmental or operating conditions) is termed aleatoric. Conversely, uncertainty is described as epistemic when it results from a lack of knowledge about a quantity whose true value (continuous or discrete) exhibits no actual variability (e.g. lack of information in the current stage of the design). Following a Bayesian approach, all the uncertainties are assigned a probability density function (PDF). Specifically, quantities with aleatoric uncertainty may be modelled as random variables through constructing their PDFs from observed data. Conversely, parameters with epistemic uncertainty may be assigned a PDF and the probability is inherently the degree of belief in a proposition. The present work addresses the epistemic uncertainty related to the location of the ship centre of gravity (CG), when optimising the hull form. Following a Bayesian approach, a probability density function (PDF) of the CG location is defined. Two complimentary formulations are presented and applied to the hull form optimisation.

## 22 Hull Girder Elastic Section Modulus as a Representative of Hull Girder Geometric Properties in Probabilistic Analyses

By Lyuben D. Ivanov

The input data for the time variant reliability calculation of the hull girder contain uncertainties. The level of uncertainty of the calculated hull girder probability of failure depends on the accuracy in the probabilistic presentation of all parameters, including hull girder geometric properties. In the paper, all hull girder geometric properties used in calculation of its bending, shear and torsion stresses are presented by their annual probabilistic distributions and probabilistic distributions for any given time period. A proposal is made for simplifying the calculations using the probabilistic distribution of the hull girder elastic section modulus (deck) as a representative of the probabilistic distributions of all other hull girder geometric properties. The example given is for a bulk carrier.

## 36 Conformal Free Form Deformation for the Optimisation of Complex Geometries

By Daniele Peri

The paper presents an approach for the deformation of complex geometries by means of Free Form Deformation (FFD). Usually, FFD is dealing with rectangular boxes including the objects to be deformed. Here an intermediate space mapping is adopted in order to include objects inside arbitrarily shaped boxes. The example of the optimisation of a propeller blade, parameterised by Conformal FFD (CFFD) is giving a practical example of the applicability of this technique to the parametric design and optimisation of complex geometries.

## 42 Simulating the Production of Future Marine Products

By Thomas Koch

The paper describes a domain oriented and knowledge based approach that creates discrete event simulation models for ship production in a straightforward, descriptive way. It uses real-world objects recognised by engineers and planners. The approach is applied to production facilities as well as to products. Another challenge addressed is the simulation of incompletely designed products for future new-building programs.

## 50 A Description of the Stationary Wave Pattern of a Marine Craft in Shallow and Intermediate Water Depths

By Björn Elsäßer & Trevor J. T. Whittaker

A stationary phase model is used to study supercritical waves generated by high speed ferries. Some general relationships in terms of wave angle, propagation direction, dispersion relationship and depth wavelength relationship are explored and discussed. In particular, it is shown that the wave pattern generated by high speed craft at supercritical speeds depends mainly on the relationship of water depth and ship speed and that the wave patterns are similar in terms of location of crests and troughs for a given depth Froude number. In addition it is found that the far field wave pattern can be described adequately using a single moving point source. The theoretical model compares well with towing tank measurements and full scale data over a range of parameters and hull shapes. The paper also demonstrates that the far field wave pattern at supercritical speeds should be non-dimensionalised by water depth and not hull length unlike it is usually done for subcritical speeds.

## 64 A Machine-Learning Approach to Predict Main Energy Consumption under Realistic Operational Conditions

By Joan P. Petersen, Ole Winther & Daniel J. Jacobsen

The paper presents a novel and publicly available set of high-quality sensory data collected from a ferry over a period of two months and overviews existing machine-learning methods for the prediction of main propulsion efficiency. Neural networks are applied in both real-time and predictive settings. Performance results for the real-time models are shown. The presented models were successfully deployed in a trim optimisation application onboard a product tanker.

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