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Editorial

Special Issue on Fatigue and Fracture Mechanics of Marine Structures

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Fatigue and fracture are important design criteria for marine structures subjected to static and cyclic loading. In particular, the ability to ensure structural integrity under all design conditions is of utmost importance for the safety of humans and the environment. Much effort has been allocated to the development of fatigue and fracture mechanic methods over the last decades; however, discrepancies between predicted and actual strength remain due to various reasons. Hence, this Special Issue aims at describing the fatigue and fracture mechanic behaviours of marine structures. In this connection, studies aiming at novel methods (either analytical, empirical, or numerical), as well as presentations of case studies or innovative test studies, are presented. This includes considerations on parameters which have a large influence on the fatigue and fracture behaviour of materials, welded joints or structural components, such as loading conditions, scale effects, etc.

Xu et al. [1] propose an improved fatigue reliability analysis method for deepwater risers using data-driven models based on response surface methods to replace physical-based models, improving computational efficiency. An annual crack growth model based on fracture mechanics considers crack inspection data, while a crack growth dynamic Bayesian network evaluates and updates the fatigue reliability of the riser. Results indicate that the proposed method accurately and efficiently analyzes riser fatigue, with crack inspection results updating random parameter distributions and the fatigue reliability of deepwater risers through Bayesian inference.

Liu and Chang [2] propose a new part-cutting constraint rule based on partial cutting for the optimization of the hull parts CNC laser cutting path, overcoming the drawbacks of traditional algorithms. A novel toolpath model for hull parts called HPCPO is proposed, and a segmented genetic algorithm based on reinforcement learning (RLSGA) is used to solve the HPCPO problem, with the population viewed as an intelligent agent. The results showed that RLSGA outperformed other algorithms and effectively solved the HPCPO problem, offering a new approach for optimizing the CNC laser cutting path of hull parts.

The study by Ahola et al. [3] focuses on improving the weld quality and lifespan of ship structures made of high-strength and ultra-high-strength steels by investigating the fatigue strength of a longitudinal stiffener detail. The research involved the use of two types of high-strength steel and gas metal arc welding with rutile-cored wires, followed by fatigue testing on small and large-scale specimens under axial and four-point bending loading conditions. The high-frequency mechanical impact (HFMI) treatment was also considered a post-weld treatment technique. The study found that using solid filler wires could potentially improve the welding quality and that repaired and post-weld-treated welds performed better in re-tests, with fatigue strength being almost twice that of the as-welded condition.

The study by Beiler et al. [4] discusses the importance of fatigue life extension methods for cruise ships or yachts that operate in freezing temperatures. The thermal cut edges of the outer shell are particularly vulnerable to crack growth, and there are currently no design curves for the fatigue assessment of thermal cut steel edges at sub-zero temperatures. To address this, fatigue tests were conducted at −20 °C and −50 °C, as well as at room temperature. The results showed that the fatigue strength at sub-zero temperatures was significantly higher compared to room temperature, suggesting that sub-zero temperatures down to −50 °C do not reduce the fatigue life of thermal cut steel edges.

The study by Gericke et al. [5] investigates the effect of thermally sprayed aluminum coatings (Al99%) on the fatigue strength and corrosion protection of gas metal arc welded (GMAW) non-alloyed structural steel specimens used for offshore wind turbines. Wöhler tests were conducted on specimens with different weld details in the as-welded condition and after thermal spray coating, along with different types of surface preparation. The study found that thermal spraying significantly increased fatigue strength, especially for specimens with welded transverse stiffeners. The corrosion studies demonstrated that thermally sprayed Al99% coatings have high resistance to corrosion in seawater environments and are suitable as sacrificial anodes for bare steel. The combination of fatigue strength improvement and corrosion protection makes thermally sprayed Al coatings a promising choice for offshore structures design and operation.

Yu et al. [6] propose a fatigue spectrum analysis and reliability analysis method for multilayer composite flexible risers. The study describes a complete fatigue and reliability analysis process for multilayer structures, which are complex structures due to the influence between layers and the range of uncertain factors. Finite element software is used to analyze the stress of the nine-layer flexible riser under the influence of upper platform structure movement and ocean current. The study also analyzes the uncertainty in the process of fatigue damage calculation and provides future research directions.

Morita et al. [7] examine the cyclic deformation behavior of mid-carbon steel under fatigue loading. Uniaxial tensile and fatigue tests are conducted to investigate the influence of loading history. The material exhibits different uniaxial ratcheting behavior depending on loading history, with a smooth and gradual increase in cyclic softening under smaller stress/strain conditions. Numerical simulations are carried out to reproduce the cyclic stress-strain behavior using the Fatigue SS Model, which can describe cyclic softening behavior within a macroscopically elastic stress state. The model is validated by the good agreement between experimental and numerical results, and a method is introduced for predicting fatigue crack initiation life under variable loading conditions based on cumulative plastic work.

Putranto et al. [8] present the application of the equivalent single layer (ESL) approach for the ultimate strength assessment of ship hull girder in numerical finite element (FE) simulations. The ESL approach replaces the stiffened panel with a single plate having equivalent stiffness, reducing the time in pre-processing and FE analysis. Two case studies, one compartment model and a full-sized double-hull tanker model, are used to demonstrate the applicability of the ESL approach. The ultimate strength predictions obtained from the ESL approach show good agreement with full three-dimensional finite element method (3D FEM) results, providing up to 3 times computational efficiency and ease of modeling.

Cho et al. [9] discuss the use of tandem submerged arc welding (SAW) to increase the welding productivity process in shipbuilding; however, the weld bead profiles produced by this process often exceed acceptance criteria specified in international regulations such as AWS D1.1, ISO 5817 and NORSOK M-101. These regulations limit weld bead profiles, particularly weld bead height, due to concerns about weldment fatigue properties. To investigate the effect of weld profiles on fatigue properties, the authors performed experiments and statistical analyses, proposing new criteria for weld bead profiles that satisfy the E curve as the design S-N curve for Tandem SAW welding.

Welding is widely used in different industries, and structural integrity assessment is vital to ensure safety due to the existence of defects in welded structures. Fracture toughness is a crucial part of structural integrity assessment, but it requires a lot of time and effort. Kim et al. [10] show that the Charpy impact test can estimate fracture behavior well in the ductile to brittle transition region for API 2W Gr.50 steel with different welding conditions; however, differences in prediction accuracy were obtained, which require additional consideration to guarantee the safety of welded structures.

The study by Petry et al. [11] aims to optimize the Voce–Chaboche (V-C) material model parameter for high-strength steel welded joints that undergo cyclic loading. The researchers used an optimization algorithm based on the Newton trust region method and an accumulated true strain parameter to determine the model parameters of each material zone in an S690 steel butt-welded joint. The results indicate that when the elastic modulus is optimized as a V-C parameter, the model slightly underestimates the strain range, leading to conservative fatigue life estimates; however, using an elastic modulus obtained experimentally can result in a non-conservative but more accurate fatigue life estimation. The study concludes that the NTR-based accumulated true strain approach successfully determined the V-C model parameters for different material zones in the welded joint, closely estimating the strain range and the fatigue life for a variable amplitude load history.

Johannesson et al. [12] focus on the mechanical life of flexible marine power cables, which are designed for mechanical loads due to movements caused by connecting devices to hubs. The Variational Mode and Effect Analysis (VMEA) reliability design method is used to identify and quantify uncertainties in fatigue life, including scatter, model, and statistical uncertainties. The VMEA method implements a load-strength approach combining numerical simulations to assess cable loads and experimental tests to assess cable strength. The study evaluates uncertainties in fatigue life for WEC system cables during the design phase using the VMEA method, which identifies weak spots in the reliability assessment and provides a foundation for evaluating safety against fatigue. Results show that the fatigue life model is a major contributor to overall uncertainty, both in terms of scatter and model uncertainty.

As Guest Editors for this Special Issue, we would like to express our sincere appreciation to the authors who have contributed their work to this collection. It has been an honor and a privilege to work with such a talented group of researchers, and we are truly grateful for the effort, time, and dedication they have put into their contributions. Each article offers unique insights and perspectives on the topic, reflecting a wide range of approaches and methodologies on fatigue and fracture mechanics of marine structures.

We have been impressed by the quality of the submissions, as well as the rigor and attention to detail demonstrated by each author. Their contributions have made this Special Issue a truly exceptional collection, one that we believe will be of great interest and value to readers in the field. Thank you again for your contributions to this Special Issue, and for your ongoing commitment to advancing scientific knowledge and understanding.

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