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Editorial

Mechanical Failure and Metal Degradation of Ships and Marine Structures

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1. Introduction and Scope

In addition to the development of ocean engineering, many ships and offshore structures have been constructed in recent years for use in shipping, oil and gas exploration, clean energy, mining and military purposes. Metallic materials such as high-strength steels, stainless steels, copper alloys and titanium alloys are widely used to build the required marine equipment. Damage to and failure of these metal components directly threaten the safety of ships, ocean platforms, offshore wind power structures, subsea vehicles, subsea pipelines, risers and cross-sea bridges. Due to the wind, wave and current loads in the ocean, ships and marine structures can suffer from serious mechanical failure, including fatigue, fracture, creepage, erosion and buckling. Additionally, metal structures are at risk of electrochemical corrosion in seawater, which could induce the degradation of ships and marine structures. The synergy of the mechanical load and corrosion could quickly lead to the failure of ships and marine structures. As a result, detecting metal damage and understanding metals' mechanisms of failure, caused by both mechanical load and electrochemical corrosion in complex marine environments, are crucial for early warnings and the protection of ships and marine structures.

2. Contributions

In this Special Issue, 10 papers are published that focus on the corrosion, buckling, fracture, coating degradation, hydrogen embrittlement and collapse of marine metals, respectively. These papers are all of high quality and provide deep insights into marine metals' mechanisms of failure, caused by electrochemical and mechanical effects. These works are significant in the field of ocean engineering.

Feng and co-authors [1] discussed a buckling analysis of corroded pipelines under the combined effect of axial force and external pressure. The simulated and experimental results indicate that corrosion plays an important role in the buckling of pipelines, especially in a subsea environment. In the following work, a new ductile fracture model was proposed to predict the fracture of X80 pipeline steel in the deep sea [2]. The void growth model was introduced in this work, and corresponded well with the experimental results.

Several studies conducted by Zhang's research team have theoretically, numerically and experimentally investigated novel structures of pressure shells subjected to external pressure [3–5]. Hydroformed toroidal shells were proposed in their recent study [3]. The octagonal cross-sections of the toroidal shells were inscribed from the circular cross-sections of perfect toroidal shells. The hydroforming performance of toroidal pressure hulls with octagonal cross-sections, together with the buckling performance of hydroformed hulls, were numerically investigated. The nonlinear finite-element method was employed to study the hydroforming and buckling performance under various hydroforming pressures. To verify the numerical findings, three nominally identical toroidal pressure hulls with discrete octagonal cross-sections were tentatively manufactured, internally hydroformed and externally collapsed. The numerical and experimental data exhibited satisfactory agreement and it was indicated that the hydroforming technique could greatly enhance the loading capacity of toroidal pressure hulls. Additionally, to improve the structural efficiency of metallic cylindrical shells under external pressure, metal–composite hybrid cylinders were proposed [4]. To evaluate the collapse pressure of steel–composite hybrid cylinders under external pressure without excessive computational cost, an analytical formula was derived that considered material failure and could reasonably predict the collapse pressure of the steel–composite hybrid cylinders with a maximum difference of 3.1%. Meanwhile, the authors investigated the effect of local corrosion on the load-bearing capacity of spherical shells [5]. The effects of the pitting distribution shape, pitting morphology and size on the ultimate buckling load were numerically studied. In addition, the analytical formula for predicting the ultimate load of a spherical cabin with random pitting corrosion was proposed and experimentally verified.

In addition to the normal mechanical failure modes, increasing attention has been paid to cracks induced by hydrogen embrittlement in recent years, especially for high-stress alloys and welding areas. The adsorption of hydrogen atoms in dislocation and grain boundaries results in the quick failure of metals. Jiang and co-authors [6] studied the effect of residual stress on the hydrogen diffusion of welded steel plates using both numerical simulation and electrochemical measurements. This work provides a research basis for controlling and eliminating the adverse effects of hydrogen on the mechanical properties of ship structures and ensuring the safe functioning of marine equipment.

Electrochemical corrosion is a prominent issue in marine structures and could lead to high economic loss. Li and co-authors [7] reported the influence of a rust layer on the passivation and localized corrosion of rebar immersed in concrete pore solution. It was found that pitting damage occurred more often on the bare steel area than on the pre-corroded area, indicating that the rust layer was able to retard pitting propagation. Zhu and co-authors [8] studied the influence of surface pretreatments on the anticorrosion performance of PPy coatings for copper alloys in seawater. Their new findings could facilitate the development of new coatings and improve our understanding of the key factors that influence coating performance. In addition to anticorrosion coatings, the effects of corrosion inhibitors such as BTA on the corrosion of copper alloys were studied by Zhang and co-authors [9]. They employed the SVET technique, which accelerated the initiation and propagation of localized corrosion in TP2 copper, while the introduction of 0.5 g/L BTA weakened the electrochemical activity of the metal. In addition, an $AlCoCrFeNi_{2.1}$ high-entropy alloy fabricated via laser surface remelting was proposed by Chen and co-authors for future marine applications [10]. The microstructure and corrosion properties were characterized and electrochemically studied. The new alloy has a wide application range in corrosion and erosion–corrosion cases in seawater. According to these corrosion studies, the enhancement of passivation and the development of coatings, inhibitors and new alloys are effective methods of protecting metals from degradation in marine environments.

3. Conclusions and Outlook

As guest editors, we sincerely thank the experts and scholars for their excellent contributions to this Special Issue, and the reviewers for their constructive comments on the manuscript.

We hope this contribution will strengthen the understanding of researchers and practitioners on recent developments and advancements in the study of mechanical failure and metal degradation in ships and marine structures. Furthermore, we hope that the results of this issue will provide a reference for future research and contribute to the ship and offshore industries.

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