IETI Transactions on Engineering Research and Practice
http://ieti.net/TERP/

2025, Volume 9, Issue 1, 35-41, DOI 10.6723/TERP.202511_9(1).0004

TECHNOLOGICAL ADVANCEMENTS IN YACHT DESIGN: HULL AND RUDDERS RECTIFICATION

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Abstract This article explores recent advancements in yacht design rehabilitation, focusing on combating osmosis and seawater corrosion, which significantly impact the structural integrity of yacht hulls and rudders. Utilizing a systematic approach to rehabilitation, including cleaning, coating, and the application of protective layers, the study documents a step-by-step process for restoring compromised yacht surfaces. A real-world application on a commissioned yacht demonstrates methods such as high-pressure washing, sanding, and the use of specialized fillers and anti-osmosis protectors to mitigate biofouling and osmotic damage. Through a blend of scientific research and practical expertise, the rehabilitation process enhances yacht resilience and prepares vessels for long-term operation in demanding marine conditions, underscoring the critical role of rigorous maintenance and innovation in yacht design. The study, supported by Ale-Yacht & Survey Sl, Spain and the Bulgarian Association of Ergonomics and Human Factors (BAEHF), showcases effective methodologies for safeguarding yacht performance and longevity.

Keywords: yacht; design; technological advancements; rectification.

1. INTRODUCTION

Yacht design, an interdisciplinary field merging maritime engineering, materials science, and aesthetic craftsmanship, embodies the peak of technological advancement in marine innovation. Yachts are not only symbols of luxury and high-end engineering but are also required to perform reliably within the relentless, dynamic conditions of marine environments, where exposure to saltwater, intense UV radiation, and variable temperatures continually challenge their durability and resilience [1-8]. These vessels must withstand a multitude of environmental stressors that can impair structural integrity, performance, and appearance over time [9-11]. Among the numerous challenges in yacht design, one of the most pressing and insidious is osmosis—a gradual, corrosive process that undermines the strength and integrity of yacht hulls and rudders by infiltrating and deteriorating the laminate structure [12-17].

To address these complexities effectively, a structured approach to hull and rudder restoration is essential. The methodology includes several core components:

- Systematic Restoration: This method involves a carefully staged process, encompassing cleaning, treatment, coating, and protective layering. Each phase contributes incrementally to restoring and enhancing the yacht's structural integrity, allowing for a complete rehabilitation that not only repairs but also fortifies the vessel against future damage. This phased approach ensures comprehensive treatment and reduces the risk of recurring issues.

- Application of Scientific Knowledge: The direct application of scientific findings in materials science and engineering enhances the effectiveness of restoration techniques. By integrating research-backed methods into practical maintenance and repair, yacht designers and technicians ensure that each solution is both theoretically sound and effective in real-world conditions. This

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bridge between theory and practice allows for improved longevity and performance of yacht structures over time.

- Advanced Techniques and Tailored Solutions: In addition to these foundational stages, yacht restoration often incorporates innovative methods such as high-pressure water cleaning, advanced fillers, epoxy resin coatings, and anti-osmosis barriers. These techniques are implemented based on the specific needs of the vessel, adapting to particular materials, structures, and usage patterns to maximize durability and aesthetic quality [18-25].

2. PRACTICAL APPLICATION AND TECHNICAL IMPLEMENTATION IN YACHT DESIGN RESTORATION

To tackle the prevalent issues of osmosis and biofouling in yachts, a documented process of structural rectification for a commissioned yacht was undertaken, showcasing state-of-the-art techniques and methodologies in hull and rudder rehabilitation. This approach not only resolved immediate structural integrity concerns but also established a replicable methodology, underpinned by scientific research and industry expertise, for future applications. The process involved systematic monitoring for early issue detection and sequential stages of treatment, coating, and protection that enhance the vessel's resilience against further damage. Technological advancements, such as high-pressure water washing, specialized antifouling paints, and precision dehydration and sanding techniques, were employed to combat biofouling, a common challenge in prolonged docked vessels. By meticulously integrating these advanced techniques, the yacht's performance was restored, and its longevity ensured, highlighting the critical role of innovation in modern yacht design restoration. Figure 1 depicts a compromised design of the yacht hull (a), propeller (b), and rudder (c). The highly osmotic areas exhibit significant damage, with some regions affected extensively. These issues are characterized by increased workload, the urgent identification of concentrated areas with deeper damage, and the subsequent escalation of repair costs for technicians working to fully restore the yacht's original design.

(a) **(b)** **(c)**

Figure 1. Compromised yacht hull and rudder design under the influence of seawater and osmosis (a) yacht hull; (b) yacht propeller; (c) yacht rudder.

After cleaning the entire surface of the hull and other adjacent components and identifying the problem areas, the process of rehabilitating the problem areas is carried out carefully as shown in Figure 2: (a) Blister with dimensions d=12mm: the hull is washed with a water jet and a painted fine layer of paint applied so that all the blisters are clearly visible and down to the smallest sizes so that they are not missed during work; (b) Blister after leveling by vibrating sander: different

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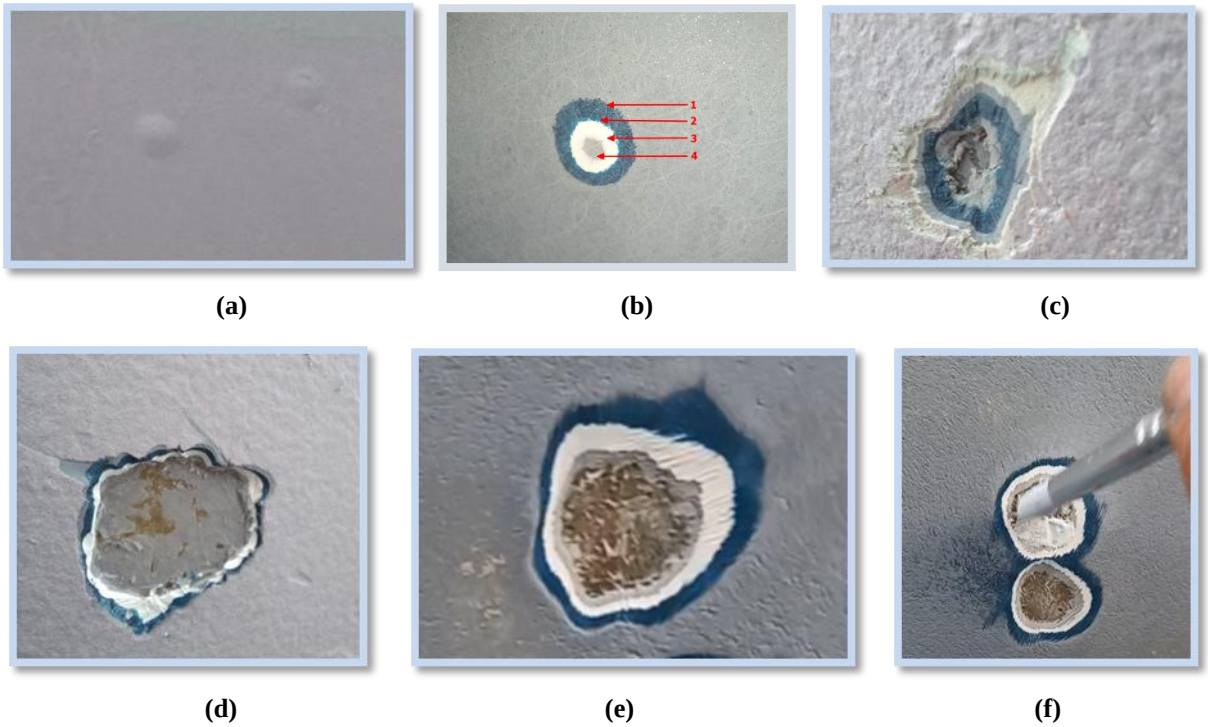
surfaces are observed due to the curved shape of the blister (1 - gray example for Antifouling, 2 - Blue - gelcoat on the underwater part of the hull, 3 - white - gelcoat (overlap of two colors of gelcoat because the position of the blister is around the waterline and as the white color is gelcoat on the surface of the hull), 4 - gray example); (c) An open blister clearly shows the need to reveal to the healthy walls of the coatings so that there are no hollow places after the treatment of the ulcer; (d) The weak border areas have been cleaned so that there are no hollow sections. It is clearly seen that the osmotic processes are from the initial stages localized between the shell and the gelcoat, without penetrating the laminates of the GRP; (e) Angled sides for more correct application of the restorative materials; (f) International Epoxy Resin Gelshield Plus: after extensive washing with water and acetone and complete drying, the first bonding and building materials of the restoration system are applied.



(a) **(b)** **(c)**

(d) **(e)** **(f)**

Figure 2. Stages of blister identification, cleaning, and hull surface rehabilitation.

Figure 3 (a, b and c) shows a process of applying materials (fillers), where problem areas are treated repeatedly, applying hard and fine fillers, and also sanding.

(a) **(b)** **(c)**

Figure 3. Process of working with hard two-component fillers on compromised areas (a) Application of first filler (material: International, Gelshield), 1 treatment out of a total of 2 + sanding ; (b) Application of second hard filler (material: International, Gelshield), 2 treatment out of a total of 2 + sanding; (c) Application of fine filler (material: Hempel, ProFiller, base and curing agent), treated 2 times + sanding.

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After the problem areas are treated individually and carefully, it is moved to a comprehensive rehabilitation with preparation for the application of an anti-osmosis protector (Figure 4).

Figure 4. Preparation for applying an anti-osmosis protector.

The selected surfaces are treated with International anti-osmosis protector material (gray and green color), applying 5 protective layers of alternating colors for proper overlap without missing areas (Figure 5).

Figure 5. A process of applying an anti-osmosis protector to the entire surface without missing areas.

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The final stage of the design rehabilitation of the yacht is completed with the application of antifouling white paint (3 coats) as shown in Figure 6.

Figure 6. Application of antifouling white color (3 layers).

3. RESULTS AND DISCUSSION

Figure 7 shows a fully completed result of the yacht's structural rehabilitation. As a result of inspections and thorough moisture analysis of the hull using the SKIPPER 5 MOISTURE METER - SMM5, there are no visible traces of previous damage to the hull and adjacent components. The total duration for this type of repair is 50 dry, sunny days, which includes the indispensable manual labor added to the technological time for grinding, cleaning with selected chemical solutions, dehydrating compromised areas, and the precise application of building and protective materials.

Figure 7. Fully finished yacht design.

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With careful work throughout the design restoration process, the overall process of successfully conducting extensive yacht repair activities is completed, emphasizing the significance for the future proper and successful operation of the yacht.

4. CONCLUSIONS

The current research has unveiled a comprehensive array of best practices and advancements in the domain yacht design rehabilitation. The primary endeavor has been to tackle the complex issues highlighted in this article, specifically, the corrosive effects of seawater and the insidious challenge of osmosis. Through the application of meticulous scientific investigation and the indispensable understanding of professionals deeply acquainted with the marine environment, innovative solutions have been uncovered.

Acknowledgements

- Ale-Yacht & Survey Sl, Spain
- Bulgarian Association of Ergonomics and Human Factors (BAEHF).

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