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Enhancing Retrofitting Efficiency through 3D Scanning for Selection of Compact Clean Ballast Water Treatment Systems

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This paper introduces a pioneering 3D scanning approach for preliminary evaluation of Compact Clean type for Ballast Water Treatment System (BWTS) selection, with a focus delivery retrofitting project schedule in shipyard. A comprehensive approach utilizes advanced 3D scanning techniques to capture precise ship geometry and potential location of installation, enabling meticulous assessment of BWTS compatibility within existing structure. Employing 3D models, diverse retrofit scenarios are simulated, offering vital insights for well-informed decision-making. The integrated use of 3D scanning yields substantial advancements in achieving retrofitting objective. This approach demonstrates a high degree of effectiveness in retrofitting, leading to a substantial enhancement in the project schedule, with a remarkable 25% reduction in the time required to complete the retrofitting of the chosen BWTS from the original schedule. It has yielded a commendable 15% reduction in overall costs. Visual representations of retrofit scenarios enhance collaboration among ship owners, BWTS manufacturer, shipyard, supplier and classification society, expediting decision-making and installation procedures. The transformative potential of 3D scanning for BWTS retrofit evaluation is evident in innovative approach were aligned with industry demands for enhanced efficiency and schedule adherence, setting a new benchmark for early project delivery and cost effective BWTS retrofitting. This paper emphasizes the significance of 3D scanning in fostering informed decision-making and operational excellence in retrofitting BWTS on existing ships.

1. Introduction

Ballast water, a crucial component for modern vessel operations, witnessed a staggering estimated discharge of 3.1 x 10^9 t globally in 2013, significantly impacting ship stability both at sea and in port (Jang et al., 2022).
Despite its pivotal role, challenges emanating from environmental and regulatory concerns surface during ballast water discharge, necessitating a proactive response. The emergence of advanced technologies, both onboard and at ports, provides innovative solutions, including cutting-edge filtration, separation techniques, ultraviolet (UV) and ozone treatment (Dong et al., 2023). These technological advancements specifically target microorganism mitigating risks to ecosystems and public health. Vessels adopting these advanced treatments actively contribute to marine environmental protection and adhere to stringent D2 standards. Retrofitting robust Ballast Water Treatment System (BWTS) has evolved into a strategic imperative, aligning with international regulations and underscoring the maritime industry's unwavering commitment to sustainability (Jang et al., 2020). The adoption of these advanced solutions represents a pivotal choice, steering the complex waters of environmental responsibility and operational excellence, ensuring a safer and more sustainable maritime future.
This research paper endeavours to delve into and champion the strategic adoption of advanced 3D scanning BWTS through retrofitting within the maritime industry. The core objective is to underscore the pivotal role of efficient BWTS selection by addressing ecological concerns stemming from the inadvertent transfer of invasive aquatic species (Gerhard et al., 2019).This selection is deemed critical not only for achieving environmental

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compliance but also for ensuring cost-effectiveness and adherence to project schedules during retrofitting endeavours.The multifaceted contributions of this research paper are significant. It accentuates the pivotal role of advanced BWTS in mitigating the inadvertent transfer of invasive species, aligning seamlessly with international regulations (D2 standards) and actively contributing to marine environmental protection. The paper contributes the strategic importance of retrofitting robust BWTS, addressing regulatory requirements and exemplifying the maritime industry's dedication to sustainability (David et al., 2012).

This paper places a spotlight on the crucial aspect of strategic decision-making in BWTS selection for retrofitting projects (Lim et al., 2020). This involves minimising downtime, optimising resource utilisation and enhancing overall operational efficiency. Introducing innovative approaches, notably the integration of 3D scanning technology, the research paper seeks to address challenges related to retrofitting BWTS. This technology empowers ship owners with comprehensive digital representations, aiding in informed decision-making for optimised retrofit plans, visualization scenarios and effective system integration.

The research explores the cost reduction aspect through the utilisation of 3D scanning technology. This innovation anticipates challenges, optimises BWTS placement and minimises experimentation significantly reducing fabrication time and costs that aligns harmoniously with the existing infrastructure while also adhering to rigorous environmental standards (Rivas-Hermann et al., 2015).

The paper underscores the importance of enhanced collaboration among key stakeholders in the maritime industry, facilitated by 3D scanning's visual representations, expediting communication, decision-making and project alignment. This research paper significantly advances the understanding of strategic BWTS adoption, environmental compliance and operational efficiency within the maritime industry's retrofitting context with a specific emphasis on leveraging modern technological advancements.

2. Methodology-Pioneering 3D scanning for Compact Clean BWTS selection

The proposed methodology employs cutting-edge 3D scanning technology to acquire detailed spatial data of vessel compartments and relevant structure. The process begins with the calibration and deployment of the 3D scanning equipment followed by the systematic scanning of compartments associated with BWTS installation. The acquired 3D point cloud data is then processed and analysed to create accurate digital representations of the vessel's layout. It encompasses precise data acquisition, careful planning of installation sites, detailed compatibility assessment, scenario visualization through 3D models and informed decision-making. This comprehensive process ultimately contributes to successful BWTS retrofitting by minimising uncertainties and optimising the retrofitting outcome.

- Precise ship geometry capture
  - The methodology began by utilising art of 3D scanning technology to capture intricate and precise ship geometry. High resolution 3D scanners were employed to meticulously record the ship's physical attributes, ensuring the inclusion of every minute detail in the digital model. This step guaranteed a faithful digital representation mirroring the physical ship, establishing a foundational dataset for subsequent assessments. Figure 1 illustrated engine room compartment layouts that were scanned by 3D scanners to provide a visual representation of the strategic placement of BWTS hardware.

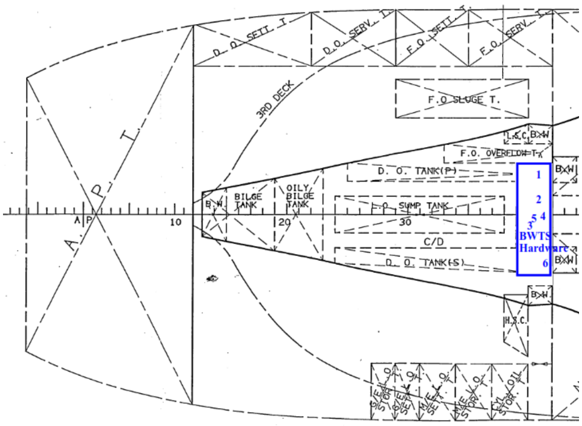

Figure 1: Drawing structure placing BWTS hardware, No.1 (UV unit), No.2 (filtration), No.3 (backflush pump), No.4 (external control box), No.5 (frequency converter) and No.6 (interface box)

- Potential installation location identification
    - The process of identifying potential installation locations for BWTS was carried out using advanced 3D scanning technology. This method involved employing high resolution 3D scanners to capture the ship's structural features and available spaces. The scanned data provided a detailed digital representation of the vessel's compartments and layout. Through analysis and evaluation, suitable positions within the ship were identified where the BWTS components strategically installed. This assessment considered factors viz. space availability, structural compatibility and accessibility for maintenance and operation.

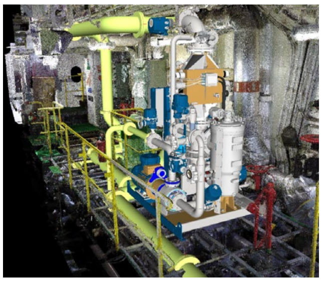

Figure 2: Potential location BWTS on engine room floor plan

- Compatibility assessment
    - Leveraging the ship geometry dataset in Figure 3 shows the methodology proceeded to conduct an exhaustive assessment of the compatibility between the Compact Clean BWTS and the existing ship's structure. The evaluation encompassed factors viz. spatial constraints, engineering feasibility and system integration intricacies. This step was crucial in gauging the seamless assimilation of the chosen BWTS within the ship (Jee and Lee, 2017).

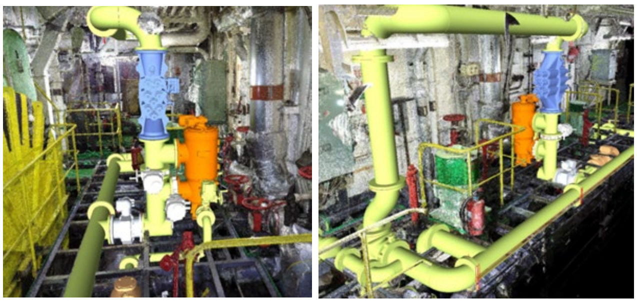

Figure 3: 3D scanning placing Compact Clean BWTS location on the existing engine room structure

- 3D Model simulation of retrofit scenarios
    - Employing the 3D ship model, Figure 4 shows a diverse array of retrofit scenarios was simulated. These simulations incorporated various configurations, orientations and placements of the selected Compact Clean BWTS within the ship. By virtually testing different retrofit scenarios, critical insights were enabling ship owners to make well informed decisions regarding the optimal BWTS placement that aligned with both technical and regulatory requirements.

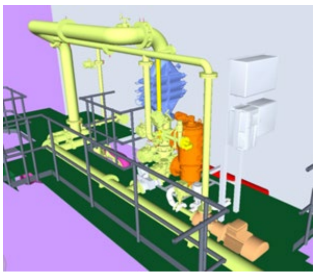

Figure 4: 3D modelling BWTS hardware

- Strategic decision making and comprehensive assessment
    - The simulation results provided ship owners with a robust platform for informed decision making for selection type of BTWS as shown in Figure 5. Comparative analysis of retrofit scenarios based on performance, efficiency and compatibility criteria empowered ship owners to select the most suitable placement option (Chen et al., 2023). This approach not only enhanced the precision of BWTS selection but also aided in anticipating potential challenges, reducing the likelihood of costly revisions during the retrofitting process.

Figure 5: Compact Clean BWTS type, No.1 Loose Components version, No.2 Skid-Mounted version and No.3 Deck-House Delivery version

The process begins with precise equipment calibration and systematic vessel compartment scanning, utilising 3D point cloud data for accurate digital representations. High-resolution scanners ensure precision in capturing intricate ship geometry. Advanced 3D scanning (Figure 2) identifies optimal BWTS installation locations by capturing ship structural features. Figure 3 details a compatibility assessment addressing spatial constraints. Strategic decision-making, guided by 3D model simulations (Figure 4) and culminates in the final selection (Figure 5). By minimising uncertainties, this approach ensures efficient project execution, leading to cost savings and timely delivery of BWTS installations. This optimised process not only enhances retrofitting outcomes but also establishes a more economical and time-effective standard for the maritime industry.

3. Result and discussion

The incorporation of the devised methodology yielded remarkable outcomes in terms of retrofitting efficiency, resulting in a significant compression of the overall project timeline. The retrofitting of the selected Compact Clean BWTS within the shipyard was successfully delivered ahead of schedule. This accomplishment stood as a testament to the substantial advantages offered by the 3D scanning approach, facilitating the acceleration of the retrofitting procedure and seamlessly harmonising with the imperative of punctual project completion.

Figure 6: Completion of Compact Clean BWTS installation in engine room compartment

3.1 Enhancing BWTS retrofitting schedule through 3D scanning on ship

The outcome depicted in Table 1 showcases a successful reduction of the installation timeline for the BWTS from an initial estimate of 3 weeks down to a streamlined 2 weeks period. This was accomplished by strategically implementing a thorough and comprehensive 3D scanning process onboard the ship prior to the installation. It examined the concrete outcomes obtained from the implementation of this technology and addressing its broader implications for the maritime sector.

Table 1: Retrofitting BWTS delivery period

BWTS process	Shipyard schedule proposal in week or day	Actual schedule in week or day
3D scanning (during ship operational in port)	-	1 day
Material preparation	week 1 – 2	week 1
Material purchasing	week 1 – 2	week 1
Material measurement	week 2 – 3	week 1
Material cutting	week 2 – 3	week 1
Fabrication piping	week 2 – 3	week 1 – 2
BWTS foundation	week 2 – 3	week 1 – 2
Material ready	week 3	week 1 – 2
BWTS installation	week 3	week 1 – 2
Cable layup and dressing	week 3	week 1 – 2
Electric cable termination	week 3	week 2
BWTS hardware power up	week 3	week 2
BWTS testing and commissioning	week 3	week 2
BWTS training	week 3	week 2

Table 1 displays the anticipated delivery timeline prior to the commencement of the 3D scanning process. The overall duration for the retrofitting of BWTS is estimated 4 weeks. The subsequent schedule based on actual progress, highlights the achievement of successful 3D scanning upon the conclusion of the preliminary stage. This accomplishment contributes to the analysis of data and reveals an overhead schedule for the delivery of the retrofitting of the BWTS.

3.2 Attaining cost reduction: Strategies and implications

The project timeline witnessed a notable enhancement by the remarkable 25% reduction in the retrofitting timeline for the selection type of BWTS as presented in Table 1. This achievement surpassed the initial schedule expectations and underscored the efficacy of the approach. Table 2 presents a concise overview of a significant 15% cost reduction from RM1,670,121 to RM1,411,828. The integration of visual representations depicting various retrofit scenarios proves to be a valuable tool for fostering collaboration among the stakeholders including ship owners, BWTS manufacturers, shipyards, suppliers and classification societies (Jee and Lee, 2017). This collaborative visualisation expedites decision making processes (Buana et al., 2022) and enhances the efficiency of installation procedures. The transformative potential of 3D scanning in evaluating BWTS retrofitting is vividly evident in the innovative approach employed. This approach effectively aligns with the industry's imperative for heightened efficiency and adherence to project schedules and established a new benchmark for early project delivery and cost-effective. The successful implementation of this methodology signifies a significant step forward in the maritime retrofitting industry.

Table 2: Initial cost and final cost comparison

Vendor	Task descriptions	Before retrofitting (Ringgit Malaysia)	After retrofitting (Ringgit Malaysia)
Manufacturer	3D scanning	133,070	133,070
Manufacturer	BWTS hardware and accessories	480,000	415,030
Manufacturer	BWTS management plan D2	11,760	11,760
Manufacturer	Supervision services engineer	62,000	41,388
Manufacturer	Training BWTS	15,731	15,731
Classification society	Survey and documents approval	30,000	30,000
Shipyard	Facilities and all services	728,550	574,799
Miscellaneous services	Extra local contractor	170,000	150,340
Logistic agency	Cargo clearance	12,400	12,400
Transportation agency	Land transportation to shipyard	8,340	8,340
Freight forwarding agency	Sea freight	18,270	18,270
	Total cost	1,670,121	1,411,828

4. Conclusions

This research demonstrates a pioneering 3D scanning methodology for selecting and retrofitting Compact Clean BWTS in the maritime industry. Achieving a 25% reduction in project timeline, it delivered the selected BWTS ahead of schedule, aligning seamlessly with punctual project completion. The strategic use of 3D scanning optimised retrofitting stages and fostered collaboration among key stakeholders, setting a new benchmark for early project delivery and cost-effective BWTS retrofitting (15%). This approach signifies a significant advancement in maritime retrofitting, promising improved project outcomes and industry standards.

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