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3D Printing in Shipbuilding and Ship Repair Industry: Challenges and Opportunities

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Abstract: In the article, the possibilities and challenges of using 3D printing in the shipbuilding and ship repair industry are discussed. This technology enables the fast and efficient production of spare parts, elements, and components required for these industries. To a certain extent, this leads to reduced repair time, faster deliveries, and lower dependence on maintaining permanent warehouse stock. Technology also allows the production of lighter, more efficient, and relatively complex structures. In addition, it helps reduce the generated carbon footprint. The challenges facing the shipbuilding and ship repair industry in the use of 3D printing are related to several aspects. The first is purely technological and focuses on integrating components produced by this method into the ship's hull structure. The second aspect is related to the certification of the parts and their durability throughout the ship's life cycle. The third aspect concerns the economic factors associated with equipment, consumables, and maintenance. Nevertheless, the method of 3D printing cannot completely replace traditional shipbuilding and repair processes, but it can support and facilitate these industries to a certain extent.

Keywords: Shipbuilding, Ship repair, Printing, 3D, Challenges

Introduction

The use of 3D printing has been known for more than 40 years. The first experiment with this type of printer was conducted in the United States in 1983. In its early stages of development, the technology was primarily used for rapid and cost-effective prototyping. Over the decades, this manufacturing method has undergone continuous improvement and modernization across virtually all industrial sectors. Today, 3D printing is employed to produce custom-designed components, architectural models, and large-scale parts for industrial applications. The emergence of Industry 4.0 and Industry 5.0 has placed industry in a state of transformation aimed at maintaining competitiveness. Shipbuilding and ship repair, as integral parts of the industrial sector, are also facing this transformation. In line with this trend, these two industries must adapt to fundamental technologies, artificial intelligence, reengineering throughout the product life cycle, and other related innovations.

The use of 3D printing for the production of ship models is presented in (Choi, 2024). This approach has proven to be particularly effective for models of high-speed vessels with high Froude numbers. An algorithm for the application of modular 3D printing in model manufacturing has been developed. The use of this approach reduces the time required for model production and allows significant modifications to the hull form design when necessary. In the manufacture of ship models intended for assessing the performance characteristics of the full-scale vessel, similarity is of critical importance, as it has a direct impact on the accuracy of the results. Experimental investigations have demonstrated a high level of accuracy when this method is employed.

Over the years, 3D printing has made significant advances across engineering industries. The emergence of 4D printing has further accelerated this process. This technology enables the creation of complex shapes and structures, which can be produced much more easily than through traditional manufacturing processes. The primary materials used in 4D printing include carbon fibers, wood-grain programmable materials, and

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programmable textiles. These materials exhibit high tensile strength and low weight, making them highly desirable for a wide range of engineering applications (Haleem,2021). The application of 3D printing as a smart manufacturing technology is presented in (Endharta,2018). This technology, together with the Internet of Things (IoT), cloud computing, and other advanced digital solutions, has been developed and implemented. Measures have been identified to improve manufacturing through optimization techniques and strategic approaches applied at various stages of the shipbuilding production process.

3D printing is a more sustainable manufacturing method compared to traditional technologies. It is not only cost-effective and efficient but also environmentally friendly, contributing to the reduction of pollution. As technology has evolved, the range of materials used has expanded significantly and is no longer limited to polymers. Different 3D printing methods have their own advantages and disadvantages, enabling the processing of both complex and simpler materials. The FDM process is among the most widely used technologies and is particularly suitable for working with polymer materials. On the other hand, one of the main challenges of SLS technology is the transportation and storage of the powdered materials used in the process (Mughir, 2022).

3D Printing in the Shipbuilding and Ship Repair Industry

The use of additive manufacturing is becoming increasingly widespread in shipbuilding and ship repair. One of the technologies included in this type of manufacturing is 3D printing. Its use enables the rapid production of components compared to traditional manufacturing methods, facilitates supply and logistics, and reduces costs. On the other hand, additive manufacturing contributes to the optimization of logistics processes by reducing the inventory of spare components for ship systems. Instead of maintaining large stocks of physical spare parts, their digital models can be stored, enabling rapid on-demand production whenever required. This approach reduces vessel downtime and improves the efficiency of repair and maintenance operations. For example, the production of a ship propeller using 3D printing technology can be completed in significantly less time compared to conventional manufacturing methods (Fig. 1).



Figure 1. 3D printed ship propeller (Ship- shape)

Current trends in the European shipbuilding industry are focused on the construction of specialized vessels designed to perform specific operational tasks. In most cases, these vessels feature more complex structural designs and components with intricate geometries, creating favorable conditions for the application of additive manufacturing technologies (Fig. 2).

The application of 3D printing in ship repair has also experienced significant development. During repair operations, this approach can be used for the rapid production of components and parts for machinery and equipment that require immediate replacement, particularly when their delivery through the conventional supply chain would involve considerable delays. Furthermore, certain stages of the 3D printing process can be carried out on board the vessel, even while it is at sea (Fig. 3).

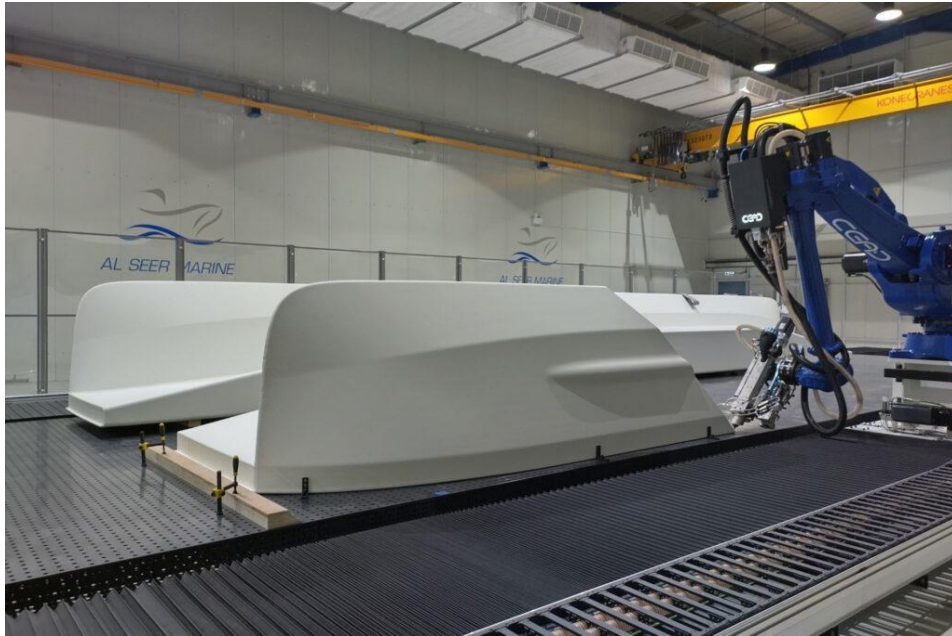


Figure 2. Catamaran hull (CEAD group)



Figure 3. 3D printed part for ship repair (The Salty Mariner)

Challenges and Opportunities of 3D Printing in Shipbuilding and Ship Repair

The challenges and opportunities of implementing 3D printing in shipbuilding and ship repair can be classified into three main groups: technical, technological, and related to certification and regulatory compliance (Figure 4). The main challenges associated with the application of 3D printing in shipbuilding and ship repair are related to the materials employed, the scale of component production, the required manufacturing accuracy, and the certification of personnel involved in additive manufacturing processes. Regarding the materials used for component manufacturing, ferrous and non-ferrous alloys, various polymers, metal powders, and rubber are commonly employed. Their application in shipbuilding and ship repair requires certification by the classification societies responsible for the survey and certification of vessels operating within the modern commercial fleet.

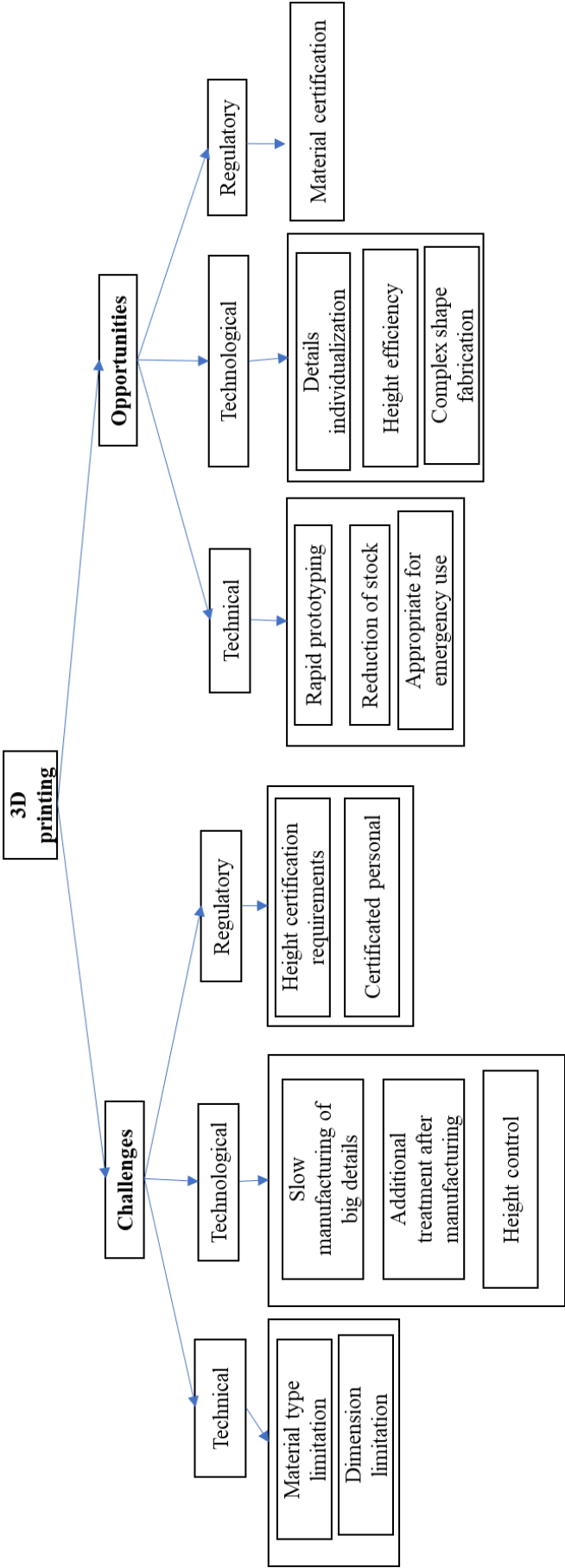


Figure 4. Challenges and opportunities of 3D printing in shipbuilding and ship repair

An important challenge for the application of 3D printing in shipbuilding and ship repair is the size and scale of the components. For this reason, this manufacturing method is currently most suitable for producing parts for marine machinery and mechanical systems. Furthermore, the manufactured components require subsequent machining to achieve the required surface roughness and dimensional tolerances where necessary. All of these requirements are met through a high level of control and precision already at the stage of designing the model for 3D printing.

A particularly important challenge is related to regulatory requirements, more specifically, those imposed by classification societies. These organizations are directly responsible for the certification of both the materials used and the operators performing the manufacturing process. The requirements are stringent, as components produced by 3D printing must satisfy all applicable mechanical strength and technological criteria to ensure their reliable and safe operation.

The potential applications of 3D printing in the maritime industry are extensive. When considered within the context of technical, technological, and regulatory aspects, these capabilities enable the implementation of this manufacturing method at various stages of shipbuilding, particularly in ship repair. From a technical perspective, the capabilities of 3D printing include rapid prototyping, reducing the need for maintaining extensive inventories of spare parts, and manufacturing components for emergency repairs.

Other significant possibilities of this manufacturing method include its high efficiency and the ability to produce customized components with complex geometries, which are commonly encountered in shipbuilding and ship repair. From a regulatory perspective, the main advantages are closely related to the certification of the materials used in the manufacturing process, ensuring the reliability, safety, and operational performance of the ship's systems.

Conclusion

The article examines the challenges and opportunities associated with the use of 3D printing in shipbuilding and ship repair. For each category, the potential challenges and opportunities are analyzed according to three criteria: technical, technological, and regulatory. The manufacturing of components involves the use of various metallic alloys, polymers, metal powders, and elastomeric materials, all of which must possess the required certifications, as this is a regulatory requirement. A significant challenge is the limitation related to the size of the manufactured components and the materials used for their production. The purpose of certification is to ensure the operational reliability and functionality of parts produced through this method. In addition, the accuracy of the digital model must be carefully controlled in accordance with the specified dimensional tolerances and the required surface quality of the finished component.

The capabilities of this manufacturing method are extensive and versatile. One of its most important advantages is the rapid production of prototypes, which significantly reduces the need to maintain large inventories of spare parts and components. High productivity is particularly valuable in dynamic industries such as ship repair, and when combined with the ability to manufacture components with complex geometries, it makes the process highly suitable for applications in the maritime sector.

Furthermore, recent amendments to the regulations of classification societies have introduced specific procedures governing the use of components manufactured through 3D printing. These developments facilitate the wider adoption of additive manufacturing technologies while ensuring compliance with safety, quality, and certification requirements.

Scientific Ethics Declaration

* The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the author.

Conflict of Interest

* The author declares that there is no conflict of interest.

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