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Study of Design and Implementation of 3D Printing in FRP Shipbuilding

Mustika Ningrum[1], Fitri Hardiyanti[2] and Heri Supomo[1,*]

[1] Department of Naval Architecture, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia

[2]Department of Shipbuilding Engineering, Shipbuilding Institute of Polytechnic Surabaya, Surabaya, Indonesia

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ABSTRACT

3D printing is becoming a more reliable and professional manufacturing method. The benefits of additive manufacturing, such as design optimization, weight reduction, and ease of prototyping, are factors that accelerate the 3D printing process. Although further research on 3D printing is still needed, in certain specific applications, it can be beneficial.

The maritime industry still predominantly uses conventional technologies in shipbuilding. Moreover, ship construction must meet strict classification requirements, which demand the use of technologies that ensure repeatability and high-quality standards.

Fiberglass, as the main material in FRP shipbuilding, and HDPE, a newer material in ship construction, can be combined to create a strong and efficient 3D printing filler material. These two materials have already proven to be suitable for shipbuilding and are supported by existing classification standards regarding thickness and structural requirements.

This study attempts to apply the use of those materials to build a 30 GT fishing vessel, with the main dimensions of the vessel as follows: LoA: 18 m, B: 4.2 m, T: 1.2 m, and H: 1.9 m.

Assuming a 3D printer nozzle size of 5 mm and a printing speed of 100 mm/s, the calculated 3D printing filler material requirement is 889 meters, with a total printing duration of 102.86 days.

Corresponding Author:

Heri Supomo
Department of Naval Architecture
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
Email: hsupomo1964 @gmail.com

INTRODUCTION

Composite materials have been widely utilized in the maritime sector. Their applications range from small boats, recreational vessels, and fishing boats to offshore structures and buildings for renewable energy (Ismail et al. 2024) (Razavi Setvati et al. 2014; Vizentin & Vukelic 2022). Composites can also be applied to specific elements of a ship, such as the superstructure, deck components, bulkheads, propulsion system elements, and piping. In addition, these materials are also used in offshore gas installations and underwater repairs (Rubino et al. 2020).

Composite materials are a combination of two or more distinct materials in a macroscopic state. Unlike metals, the constituent components of composite materials—namely, fibers and matrix—can still be observed without the use of magnifying tools. The fibers in a composite serve to reinforce the matrix, as they generally possess higher stiffness than the matrix. Meanwhile, the matrix functions as a binder that holds the fibers in place and provides protection against environmental exposure and impact damage (Rique et al. 2015; Aslam Shaikh et al. 2022).

In the construction of Fiberglass Reinforced Plastic (FRP) vessels, the fiber used is typically fiberglass, while the most commonly used matrix is an epoxy-based catalyst. Based on standard strength and structural calculations, the vessel must meet a minimum tensile strength of 98 MPa and a bending (flexural) strength of 150 MPa(Indonesia 2021).

The lamination method is the most commonly used conventional technique in FRP shipbuilding, as it is the simplest method with the lowest production cost. However, a key drawback of this method is the inconsistent bonding between each layer of fiberglass and resin, which can lead to uneven structural integrity(Praharsi et al. 2019).

The production of fiberglass vessels is currently still conventional, with most manufacturers relying on the hand lay-up and vacuum infusion methods. These techniques present several issues, such as the formation of air bubbles trapped within the FRP layers, which reduce the overall strength of the vessel, as well as the lengthy production time required.

3D printing technology, also known as additive manufacturing (AM) or rapid prototyping (RP), is a controlled robotic process that builds objects layer by layer from a CAD environment using 3D computer design programs. In 3D printing, the printing speed depends on the complexity of the design and the size of the object. The mechanical properties are determined by the printing orientation, which is configured through process settings within the layering method. This orientation becomes one of the most critical parameters influencing the speed of 3D object formation.

The output of a 3D printer is uniform according to the defined layer thickness, and also possesses measurable mechanical properties that align with the design specifications (Bayramoğlu et al. 2019; Vemuganti, Soliman & Taha 2023)

One example of a 3D printing filler material is Polyethylene (PE)—a versatile polymer that is no longer entirely dependent on fossil fuels. Thanks to advancements in green chemistry, the ethylene monomer (C_2H_4) used to produce PE can now be derived from bio-ethanol sourced from sugarcane or starch, making PE a bio-based material.

However, due to its saturated carbon chain, PE remains resistant to microbial attack, meaning it is not biodegradable. It can only be broken down through chemical or mechanical processes, such as recycling (Agrawal & Bhat 2025).

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The advantage of PE lies in its ability to be modified into various types through chain density engineering:

- LDPE (Low-Density Polyethylene) — Its heavily branched structure makes it flexible and transparent. Thin films made from LDPE dominate applications such as food packaging, shopping bags, and protective layers for personal care products(Agrawal & Bhat 2025).
- HDPE (High-Density Polyethylene) — Its straight and tightly packed molecular chains enhance tensile strength and chemical resistance. It is used in milk jugs, shampoo bottles, water pipes, and even automotive fuel tanks(Agrawal & Bhat 2025).
- UHMWPE (Ultra High Molecular Weight Polyethylene) — Has an extremely long molecular mass, resulting in exceptional impact resistance. UHMWPE fibers and sheets are used in armor plates, prosthetic joints, and automotive gear components that operate under high loads(Agrawal & Bhat 2025).

HDPE is also used as the primary raw material for HDPE vessels and is regulated under BKI (Bureau of Classification Indonesia) for special-purpose ships (Klasifikasi Indonesia 2023).

Therefore, in this study, the author aims to examine the potential of combining fiberglass, the primary reinforcement material in FRP vessels, with a 3D printing filler made from HDPE. The research hypothesis suggests that this material and method combination will produce a strong and efficient composite with minimal defects, due to the precision and control offered by the 3D printing process.

METHOD

Manufacturing Process of HDPE and Shredded FRP Composite Filler:

1. FRP is shredded into small pieces resembling fine hair strands, with lengths ranging from 1 to 3 mm.
2. HDPE pellets are then mixed with the shredded FRP.
3. The HDPE–FRP mixture is now ready to be molded into 3D printing filler. The molding process is illustrated in Figure 1.

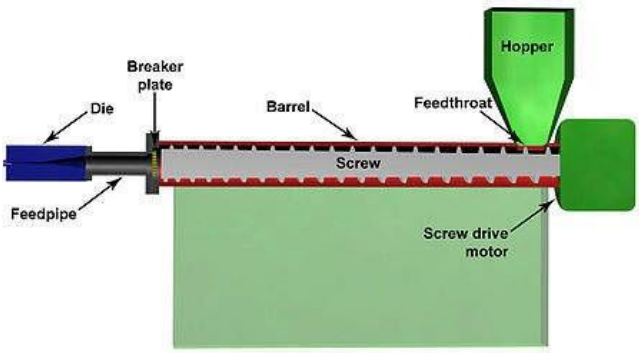

Figure 1. Diagram of a 3D Printer Filler Extrusion Tool

Printing Process of the Vessel to be Built:

1. 3D Model Design (CAD)
   Designing the object using Computer-Aided Design (CAD) software as the basis for the shape and structure of the print.
2. File Conversion to STL
   Converting the CAD design into STL (Standard Tessellation Language) format so it can be read by the 3D printer.
3. File Setup on the Printer
   Importing the STL file into the 3D printer's software and configuring parameters such as orientation, size, layer height, and printing speed.
4. Machine Preparation
   Preparing the printer, including loading materials (filament or resin), heating the nozzle, and performing calibration if necessary.
5. Printing Process
   The machine begins printing the object gradually, layer by layer, according to the digital design. Printing time depends on the size and complexity of the object.

6. Part Removal
   Once printing is complete, the object is carefully removed from the build platform to avoid damage.
7. Post-Processing
   Finishing processes such as surface smoothing, removal of leftover material, or assembly if the object consists of multiple parts. As shown in Figure 2.

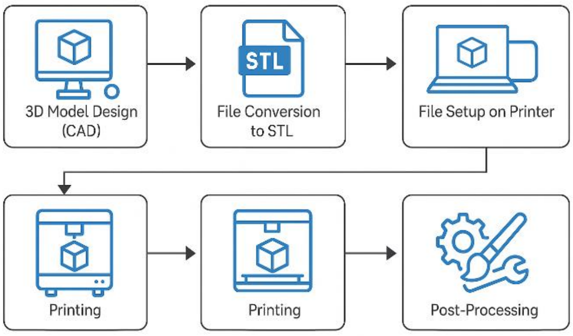

Figure 2. 3D Printing workflow

RESULTS AND DISCUSSION

The vessel used in this study is a 30 GT fishing vessel, with its principal dimensions shown in **Table 1**.

Table 1. Main Size Data of Fishing Vessels

LOA	18,00 m
B	4,20 m
T	1,30 m
H	1,90 m

And the lines plan of the vessel can be seen in Figure 3, which will be used as the basis for creating the 3D design of the fishing vessel.

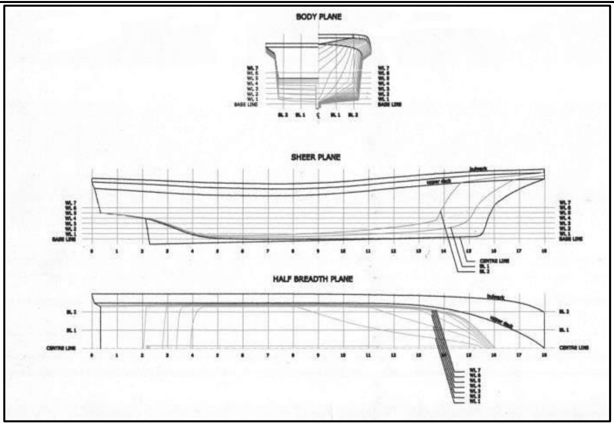

Figure 3. Lines Plan for 30 GT Fishing Vessels

After creating the 3D hull design of the vessel, it is also necessary to calculate the ship's structural components. Based on the calculations, the following data were obtained:

Table 2. Ship Construction Calculation Results

Parts Name	Wide (m^2)	
Hull		
keel	7,81	m^2
bottom plate	46,68	m^2
side plate	118,47	m^2
Construction and Profile		
Side Longitudinal	31,84	m^2
Centre Girder	6,13	m^2
Side Girder	16,60	m^2
Frame	42,82	m^2
Floor/Wrang	4,63	m^2
Partition		
Bulkhead Wall	30,67	m^2
Bulkhead	36,20	m^2
Deck and Superstructure		
Deck	55,50	m^2
Superstructure & Cabin	58,94	m^2
Construction and Profile		
Deck Beam	40,68	m^2
Deck Longitudinal	40,03	m^2
Upper Building Fixer	26,14	m^2
Upper Building Beam	20,35	m^2

Based on the data above, calculations can be made to determine the volume of the vessel's structure (Table 3). This data is then used to calculate the amount of 3D printer filler material required as well as to estimate the printing time needed.

Table 3. Calculation results of the number of laminations

Part Name	Wide (m^2)	Thick (mm)	Volume (m^3)
Keel	7.81	15.12	118
Base	46.68	12.00	560
Side	118.47	10.00	1185
Deck	55.50	7.01	389
Frame	42.82	6.00	257
Deck Beam	40.68	6.00	244
Side Longitudinal	31.84	6.00	191
Deck Longitudinal	40.03	6.00	240
Bulkhead and Tank Stiffeners	36.20	4.75	172
Centre Girder	6.13	15.00	92
Side Girder	16.60	15.00	249
Wrang	4.63	6.12	28
Bulkhead Wall	30.67	5.70	175
Superstructure and Cabins	58.94	7.00	413
Upper Building Fixer	26.14	5.00	131
Total	563.14	126.70	4444

By assuming a nozzle size of 5 mm, the calculated requirement for 3D printer filler material is 889 meters. With an estimated 3D printing speed of 100 mm/s, the total time required to print the entire vessel with the dimensions mentioned above is approximately 2,468.64 hours, or 102.86 days.

CONCLUSION

The use of 3D printing opens up numerous possibilities in shipbuilding, such as reducing storage space, shortening the supply chain, minimizing lead times, lowering production costs, optimizing part designs in ways previously unattainable, and utilizing materials that were not easily applicable in conventional engineering processes.

The combination of HDPE and FRP indeed presents a promising material to be developed as a 3D printing filler for ship construction. However, future research is still needed to determine the optimal size of FRP fragments used in the mix, as well as the development of large-scale 3D printers specifically for shipbuilding, considering that vessels are not small in size and require specialized printing capacity to achieve practical implementation.

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