MODELLING AND 3D PRINTING OF MARINE PROPELLER

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Abstract – A propeller functions as a fan-like mechanism comprising a central hub connected to blades arranged radially around it. It operates by harnessing power generated by the ship's engine, which is transmitted through a shaft mechanism. This power is then converted into rotational motion, causing the blades to spin and generate thrust, propelling the ship forward through the water. These blades impart a thrust force that transmits momentum to the water and drives the ship forward. The design of these propellers and their methods of manufacture ultimately determine their overall efficiency. Traditional manufacturing processes for propellers often involve complex casting or machining techniques, which can be time-consuming and costly. With the advent of additive manufacturing, particularly 3D printing, there has been a paradigm shift in the fabrication of marine propellers. This project explores the latest advancements in modelling and 3D printing techniques for marine propellers, focusing on their design optimization, material selection to optimize the performance. Utilizing Advanced Computer-Aided Design (CAD) software, a detailed digital representation of the Marine propeller will be created. Subsequently Additive Manufacturing techniques were employed to produce physical prototypes. A CAD model was built using SolidWorks (2022) software in the form of SLDPRT format, and that file will be saved as a STL file. Then, it will be sent to a 3D printer for printing of the part using 3D printing technology, which converts the digital design of the object into a physical part.

1.INTRODUCTION

Marine propellers are essential components within a watercraft's propulsion system, enabling the vessel to navigate through water. These rotating devices, resembling fans, are designed to convert the engine's power into thrust, propelling the boat forward. They are widely used in various watercraft like ships, boats, submarines, and underwater vehicles. The design and engineering of marine propellers are intricate and specialized. Factors such as blade size, shape, pitch angle, blade count, and material composition are carefully optimized for performance and efficiency. Propeller geometry, including blade area distribution and twist, is customized based on specific vessel types and operating conditions such as speed, load, and water conditions. The operation of a marine propeller follows Newton's third law of motion, stating that for every action, there's an equal and opposite reaction. As the propeller blades rotate, they create a pressure difference between their front and rear surfaces, resulting in water moving backward and generating forward thrust.

Classification of marine propellers:

Propellers are be classified on the basis of several factors. The classification of different types of propellers is shown below:

1. Based on number of blades
   1. 3-Blade propeller
   2. 4-blade propeller
   3. 5-Blade propeller
   4. 6-Blade propeller
2. Based on pitch
   1. Fixed pitch propeller
   2. Controllable pitch propeller

3D PRINTING

3D printing, also known as additive manufacturing (AM), is a revolutionary technology that has transformed the way we design, create, and produce objects. Unlike traditional manufacturing methods that involve subtracting material from a solid block, 3D printing works by building objects layer by layer from digital models or electronic data sources. This additive process allows for incredible flexibility, customization, and complexity in the objects that can be produced. The concept of 3D printing dates back to the 1980s when early equipment and materials were developed. Over time, advancements in technology, materials, and processes have made 3D printing more accessible and versatile across a wide range of industries and applications.

Methods of 3D Printing:

1.Stereolithography (SLA)
2. Selective Laser Sintering (SLS)
3. Fused Deposition Modelling (FDM)
4. Digital Light Process (DLP)
5. Poly-Jet
6. Direct Metal Laser Sintering (DMLS)

In 3D printing, a variety of materials can be used, including plastics, metals, ceramics, and even biomaterials. This versatility allows for the creation of diverse objects, from prototypes and functional parts to artistic creations and medical implants. Engineers, designers, and artists can quickly bring their ideas to life, test concepts, and make adjustments with minimal time and cost compared to traditional manufacturing methods. The applications of 3D printing span across industries such as aerospace, automotive, healthcare, fashion, education, and more. It is used for creating intricate components, customized products, medical devices, architectural models, fashion accessories, and even food items.3D printing offers a significant advantage in the rapid prototyping and iteration of designs. This capability is one of the key strengths of the technology, enabling designers, engineers, and innovators to bring their ideas to life quickly and efficiently. With traditional manufacturing methods, creating prototypes and iterating designs can be time-consuming and costly. It often involves creating molds, tooling, and machinery setups, which can take weeks or even months. Additionally, any design changes require modifications to these physical components, further adding to the time and cost.

How 3D printing useful in Marine Industry?

Marine engineers and designers use 3D printing to rapidly create prototypes of various components such as propellers, hull designs, and specialized parts. This allows for quick iteration and testing of designs, leading to faster development cycles. One of the key benefits of 3D printing is its ability to produce customized components tailored to specific vessel requirements. This includes creating unique propeller designs for different types of ships or manufacturing personalized parts for specialized marine applications. Additive manufacturing processes like 3D printing excel in producing complex geometries that are challenging or impossible to achieve using traditional manufacturing methods. This capability is highly beneficial for creating intricate marine components with optimized shapes for enhanced performance and efficiency.3D printing enables on-demand manufacturing of marine parts and components. Instead of relying on large-scale production runs and maintaining extensive inventories, manufacturers can produce parts as needed, reducing lead times and storage costs. For low-volume production or specialized components, 3D printing can be more cost-effective than traditional manufacturing processes. It eliminates the need for expensive tooling, reduces material waste, and allows for efficient production of custom or unique parts. With advancements in 3D printing materials, marine engineers have a wide range of options to choose from, including high-performance polymers, metals, and composites. This enables them to select materials based on specific performance requirements such as strength, durability, corrosion resistance, and weight savings. 3D printing is also valuable for repair and maintenance operations in the marine industry. It enables the rapid production of replacement parts, reducing downtime and costs associated with waiting for spare components to be sourced or manufactured.

2.LITERATURE REVIEW:

A. Johnson and B. Smith [1] introduces the concept of using modeling and simulation techniques specifically tailored for 3D printing marine propellers. The authors discuss the importance of accurate modeling in achieving optimal performance and efficiency. They explore various simulation tools and methodologies that can simulate fluid dynamics, structural stresses, and material behavior to ensure that 3D printed propellers meet the required performance standards.

Taylor and Clark [2] explore optimization techniques tailored specifically for 3D printed marine propellers. They discuss methodologies such as genetic algorithms, topology optimization, and parametric design to fine-tune propeller designs for improved efficiency and reduced material usage. The paper emphasizes the role of optimization in achieving lightweight yet robust propeller structures through additive manufacturing.

Singh and Sharma [3] explore hybrid manufacturing approaches that combine additive manufacturing (3D printing) with traditional machining methods for marine propellers. They discuss how hybrid techniques can leverage the strengths of both processes, such as intricate geometry creation through 3D printing followed by surface finishing and precision machining, to achieve high-quality propeller components with enhanced performance characteristics.

Taylor and Clark [4] explore optimization techniques tailored specifically for 3D printed marine propellers. They discuss methodologies such as genetic algorithms, topology optimization, and parametric design to fine-tune propeller designs for improved efficiency and reduced material usage. The paper emphasizes the role of optimization in achieving lightweight yet robust propeller structures through additive manufacturing.

Garcia and Rodriguez [5] focus on topology optimization techniques specifically tailored for marine propellers fabricated using additive manufacturing. They discuss how topology optimization algorithms can iteratively redesign propeller structures to achieve lightweight yet structurally robust configurations, taking into account loading conditions, material properties, and manufacturing constraints imposed by 3D printing processes.

Chen and Patel [6] explore the challenges and opportunities in additive manufacturing of composite-based marine propellers. They discuss the benefits of using composite materials such as carbon fiber reinforced polymers (CFRP) for 3D printing propellers, addressing issues related to composite fabrication techniques, material compatibility, and performance enhancement through tailored composite designs.

Li.Chen and Li [7] conduct a lifecycle analysis of 3D printed marine propellers, assessing factors such as initial manufacturing costs, operational lifespan, maintenance requirements, and potential refurbishment or recycling options. They discuss strategies for extending propeller lifespan, optimizing maintenance schedules, and implementing circular economy principles to minimize waste and environmental impact throughout the propeller's lifecycle.

3.METHODOLOGY:

Modelling of Marine propeller:

SolidWorks is a 3D solid modelling package which allows users to develop fully solid models in a simulated environment for both design and analysis. In SolidWorks, the ideas and experiment with different designs to create 3D models. SolidWorks is used by students, designers, engineers, and other professionals to produce simple and complex parts, assemblies, and drawings. Designing in a modelling package such as SolidWorks is beneficial because it saves time, effort, and money that would otherwise be spent prototyping the design. Using SolidWorks marine propeller model is created.

1. Sketch the Blade Profile:

- Open SolidWorks and start a new part
- Select the "Front Plane" from the Feature Manager Tree.
- Use sketch tools like lines, arcs, and splines to draw the profile of one propeller blade.
- Ensure the sketch is fully defined and symmetric if needed for a symmetrical blade.
- Add dimensions to define the blade's size, shape, and key features accurately.

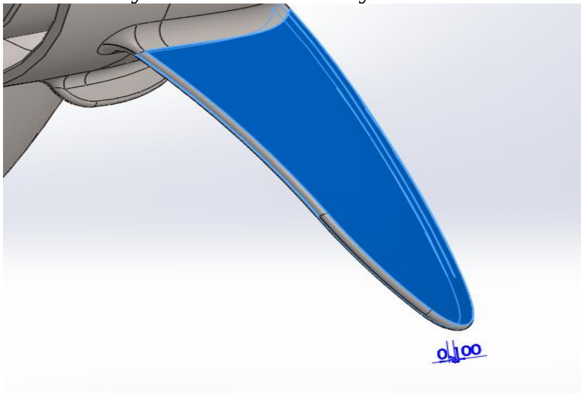

Fig 1. Design of blade

2. Revolve the Blade Profile:

- With the blade profile sketch selected, go to the "Features" tab and choose "Revolve Boss/Base."
- Set the axis of revolution as the centerline of the blade profile sketch.
- Specify the angle of revolution (typically 360 degrees) to create a full blade.
- Click "OK" to revolve the sketch and create the 3D blade shape.

3. Add Blade Features:

- Use additional sketches and features to add details like twist, taper, and curvature to the blade.
- Create sketches on planes perpendicular to the blade axis for these features.
- Use extrude, cut, and fillet features to refine the blade shape

4. Model the Hub:

- Sketch and model the hub where the blades converge.
- Consider factors like blade attachment, shaft connection, and hub geometry based on your propeller design requirements.

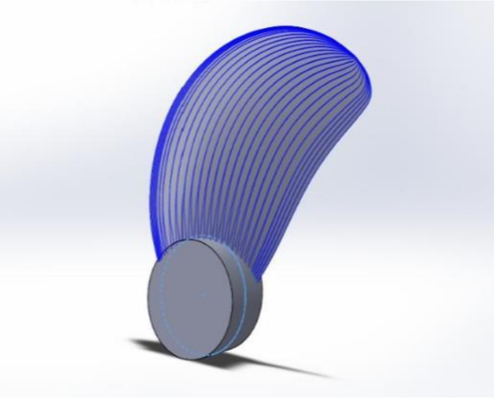

Fig 2. Hub and Blade

- See revolving of blade with the option of circular pattern around it.

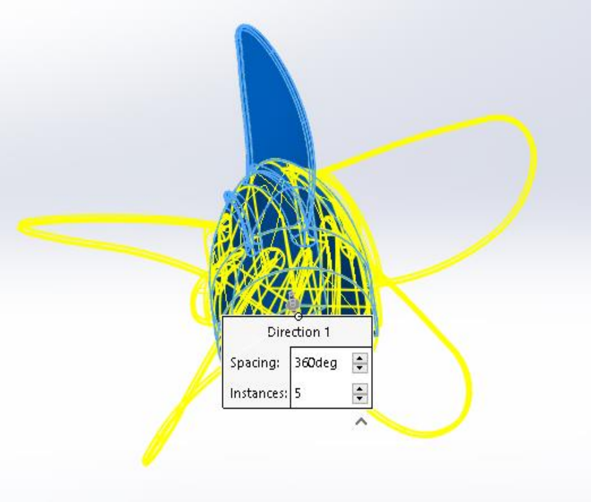

Fig 3. Repetition of blade

5. Add Fillets and Chamfers:

- Apply fillets and chamfers to smooth edges and transitions between features.
- Fillets can improve aerodynamics and reduce stress concentrations, while chamfers can add strength and aesthetic appeal.

6. Check for symmetry and accuracy:

- Ensure the model is symmetric if the propeller has required number of blades.
- Check dimensions, clearances, and geometric relationships to ensure accuracy and adherence to design specifications.

7. Review and iterate:

- Review the model for any design flaws, inaccuracies, or performance issues.
- Make iterative adjustments based on simulation results, feedback, or design optimizations to improve the propeller's performance and efficiency.

8. Document and save:

- Document the design process, including dimensions, materials, simulations, and any design iterations.
- Save the SolidWorks part file (. sldprt)

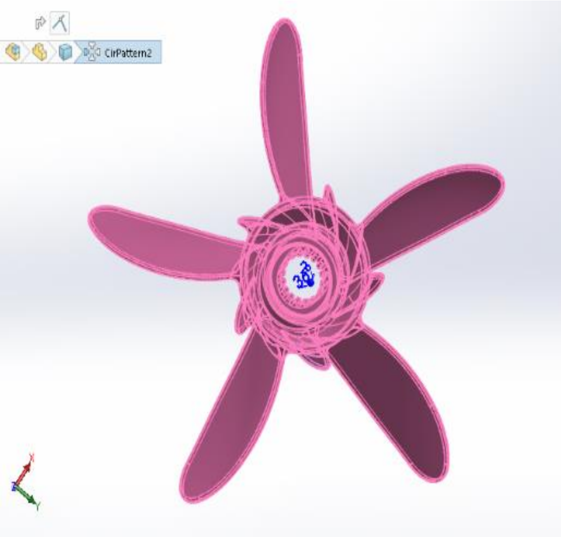

Fig 4 Final propeller

3D Printing of Marine propeller

Step 1:

- Develop the CAD Model
- Designing the 3D model using 3D modelling software like SOLIDWORKS or CATIA. Utilize the modelling tools within the software to create the desired design.

Step 2:

- Convert the CAD Model into. STL File Format.

Step 3: Open the FlashForge 3D Printing Software

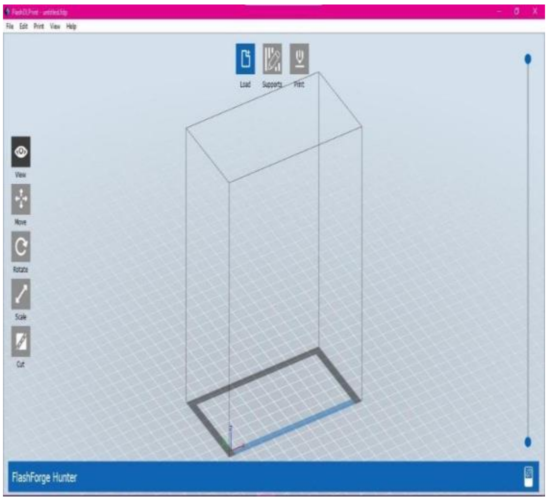

Fig 5 Overview of 3D printing software**.**

Step 4:

- Load and Adjust the STL File in the FlashForge Software

Step 5:

- Selecting and Generating Supports in the FlashForge Software

Step 6:

- Configuring Printing Settings in the FlashForge Software.

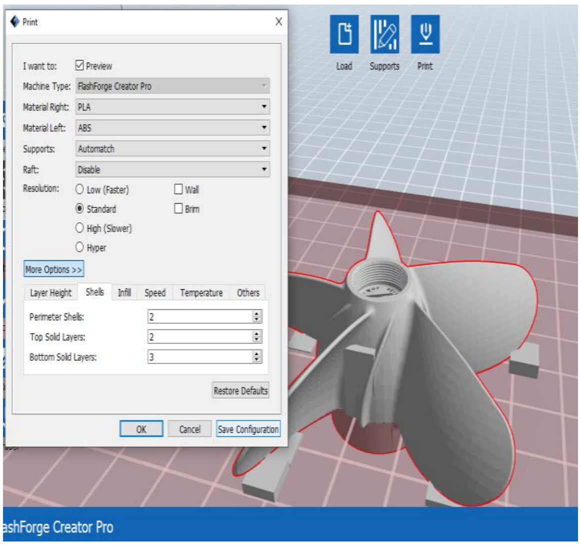

Fig 6 Setting shells

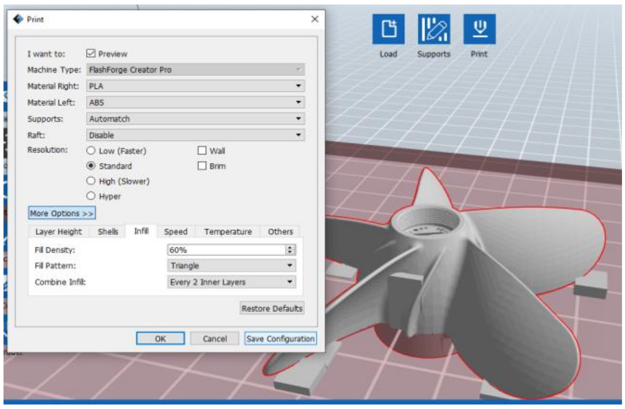

Fig 7 Setting infill

Step 7: Saving the Sliced Model and Estimating Print Time.

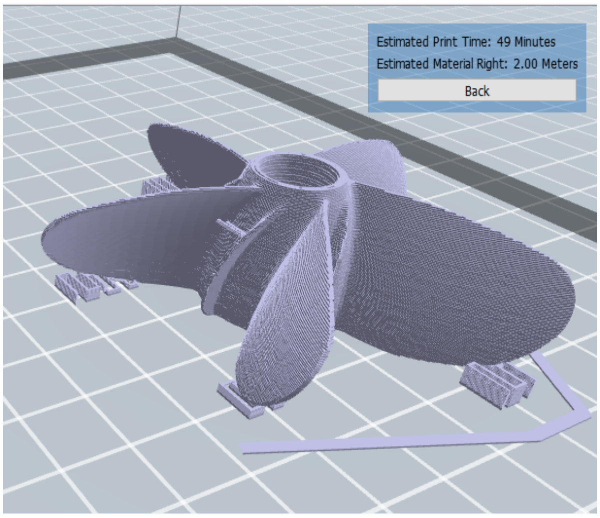

Fig 8 Final estimated print time

Step 8: Taking out the printed model out.

RESULT

Designed 3D model of the Marine propeller converted to the required file format, configured with suitable support structures, and ready for 3D printing. The model is saved in the appropriate file format (*. svgx or *.fdp) with all the necessary settings adjusted, such as material selection, resolution, layer height, infill density, and fill pattern. The software provides an estimated printing time for the material based on the configured settings. the digital design of marine propeller converted into physical part . 3D printing facilitates rapid prototyping of propeller designs, allowing engineers to quickly iterate and test multiple iterations. This accelerates the design optimization process and reduces time to market for new propeller designs. Compared to traditional manufacturing processes that require expensive tooling and machining, 3D printing can be more cost-effective for small-batch or customized propeller production. This not only saves time but also significantly reduces material waste as the additive manufacturing process is highly precise and material-efficient.

Fig 9 3D printed propeller

Estimated time: 1hr 30min

CONCLUSION

In conclusion, the designed and properly prepared 3D model of the marine propeller was successfully created. The application of 3D printing proved to be a practical and effective method for manufacturing marine propeller, offering advantages such as customization, cost-effectiveness, and efficient production. The utilization of 3D printing technology enables the production of complex geometries and optimized designs, resulting in improved performance and efficiency of the marine propeller. In other machining processes to make an object the material is removed from the object but in 3-D printing technology the material is added to produce a required component, due to this the wastage of material eliminated and it gives good accuracy and finish. This technique is not good enough from mass production point of view, but manufacturing some complex items which instead would take many days in workshop can be created using this technique. This technique in our view it might be a revolution in manufacturing field in coming years proving its importance in each and every aspect of life.

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