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Underwater Vehicle for Detecting Ship Hull Damage

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Abstract: - Proposed system for underwater vehicle hull inspection utilizes the camera technology to identify structural damages and sea growths on ship hulls. Equipped with precise imaging, the vehicle autonomously detects and locates areas of concern, transmitting the exact coordinates to authorized devices in real time. This approach eliminates the need for human divers to physically examine the hull, enhancing safety and efficiency, regardless of time and anywhere while voyage or sailing. The vehicle operates through a stable Ethernet power source, ensuring consistent communication and energy supply. By minimizing human intervention, this system aims to streamline underwater inspections, improving maintenance processes and reducing operational risks and cost.

Keywords: Underwater vehicle, Ship Hull Detection, damage, cracks, sea growth, camera, Divers reduced, Cost effective

I. INTRODUCTION

In the maritime industry, the maintenance and inspection of underwater ship hulls are critical for ensuring vessel integrity, performance, and safety. Traditionally, this process has relied heavily on divers to manually inspect the ship's hull, searching for damages such as cracks, dents, or corrosion, as well as the accumulation of sea growth like barnacles and algae. Although effective, this method presents significant risks to divers, including underwater hazards, limited visibility, and the challenges of working at great depths. In addition, manual inspections are time-consuming because we need to get an appointment from divers priorly. With advancements in technology, the use of underwater vehicles for hull inspection has emerged as a safer and more efficient alternative [1]. These vehicles are fitted with camera and other sensors (Pressure, Gyroscope) that can capture high-quality images and identify damage to hulls as well as the presence of marine or sea growth. The vehicle uses the onboard camera to scan all over the ship's hull, if cameras detected any damages or areas of concern, the vehicle pinpoints the exact location of the issue and transmits this data to an authorized device, such as a monitoring station or a ship maintenance crew's handheld device. The system is powered through an Ethernet cable, providing a reliable source of energy and enabling continuous data transmission. This tethered power system ensures that the vehicle can operate for extended periods, making it ideal for comprehensive inspections of large vessels [2].

This paper presents the concept and design of an underwater vehicle for detecting ship hull damage aimed to make the maintenance ease and reducing reliance on divers and introducing a more automated, reliable, and cost-effective solution for the maritime industry.

II. LITERATURE REVIEW

This method uses camera technology to do thorough hull inspections, in contrast to previous ROVs that relied on proximity sensors and optical imaging for navigation and obstacle recognition and deformation in ship hull. Although proximity sensors are useful for avoiding collisions and keeping a safe distance from objects, they are unable to record the minute details required for precise damage assessment. Our approach, on the other hand which utilizes camera technology to capture high-resolution images of the hull, enabling more precise and comprehensive identification of defects like corrosion and cracks, sea growth and thereby enhancing the reliability, efficiency and cost of the inspection process.

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III. Proposed System

The proposed system represents a significant technological advancement and game-changer in the maritime industry, revolutionizing ship hull inspection processes. By minimizing the time, cost, and need for human intervention in manual inspections, this system enhances operational efficiency and safety and even can be used during voyage, enabling timely detection of damages without disrupting operations. The vehicle is effective to do an inspection to find the damages on the ship hull. The below mentioned damages can be found through these inspection

A. Dents and Physical Damages Inspections:

The ship vessels are constantly exposed to the harsh condition that leads to huge damage in hull due to hazardous beneath the surface such as rock, debris, ice berg in cold region these damages can be inspected by the vehicle.[3]

B. Sea Growth and Biofouling Inspection:

Ships are highly prone to the rapid accumulation of sea growth often called as biofouling. where marine organisms such as barnacles, algae, and molluscs latch onto the hull leads to significant structural damage over time, compromising the vessel's integrity and efficiency. Regular monitoring of biofouling is essential to identify its extent and ensure timely corrective measures are taken to mitigate its adverse effects.

C. Cracks and Fracture Inspection:

Cracks and fracture are the serious issue that comprise the ship vessels. These cracks typically occur due to repeated stress and fatigue over time, especially in areas where the hull experiences high mechanical loads. Additionally, extreme temperature changes or improper welding during hull construction can cause stress concentrations, which can further initiate or propagate cracks. This issue can be monitored and ensure of maintaining it.

D. Cavitation Inspection:

Cavitation damage in ships refers to the formation and subsequent collapse of vapor bubbles in the water surrounding the hull and propellers, which can lead to significant erosion and structural damage.[4] The camera can detect these pits or small surface imperfections that occur due to cavitation.[5]

E. Corrosion Inspection:

The deterioration of a ship's hull is caused by the persistent contact with water, abrasive materials, and ocean debris encountered during sea voyages. Continuous water flow and sediment impact gradually erode the protective coatings and metal surfaces of the hull. To mitigate the effects of erosion, regular inspections and maintenance are essential. Utilizing an underwater vehicle equipped with a high-resolution camera allows for efficient detection and monitoring of corrosion, enabling timely interventions to preserve the vessel's structural integrity and operational efficiency.

IV. Mechanical Design

Body:

The vehicle's body is designed with a streamlined hydrodynamic shape to minimize drag and ensure smooth movement through water. The material used is acrylic tube as it is water proof so that it will prevent water entry and electronics damage. The frames connected to the body are made up of PVC pipe as it is light weight. I have covered all the nooks and joining edges with resins.

A buoyancy control mechanism adjusts the vehicle's depth with precision, crucial for close-proximity inspections. Adding a buoyancy foam allows the vehicle to achieve neutral buoyancy.

Propulsion system:

The design of this underwater vehicle has 6 motors to acquire a great reliability and stable maneuverability in aquatic environments.

The two thruster motors, positioned at the rear end of the vehicle, provide forward and backward propulsion, allowing the vehicle to navigate efficiently through the water (forward or backward).

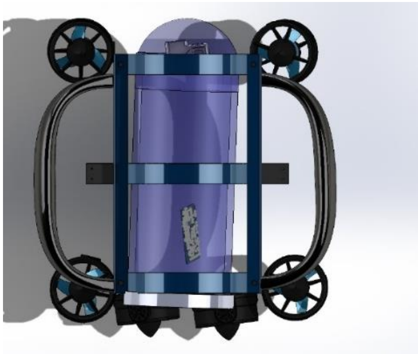

Fig 1. Top view of the underwater vehicle

Fig 1 depicts the position of other four motors responsible for vertical motion, they are strategically placed to control the vehicle's ascent and descent. These vertical motors are typically mounted symmetrically on the vehicle, two on each side, to maintain balance and ensure smooth, controlled up-and-down motion. This will provide a great 6 degrees of aerodynamics such as Surge, Sway, Heave, Roll, Pitch, Yaw.[6] [11]

Camera Mount and Protective Dome:

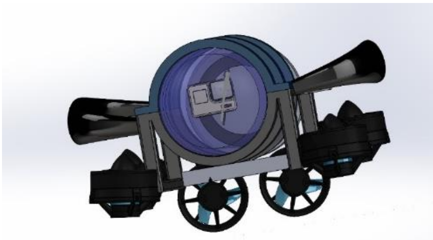

Fig 2. Front view of the underwater vehicle

Fig 2 shows the position of camera. The camera is securely mounted within the waterproof and pressure enclosed dome to ensure functionality at varying depths.

Block Diagram:

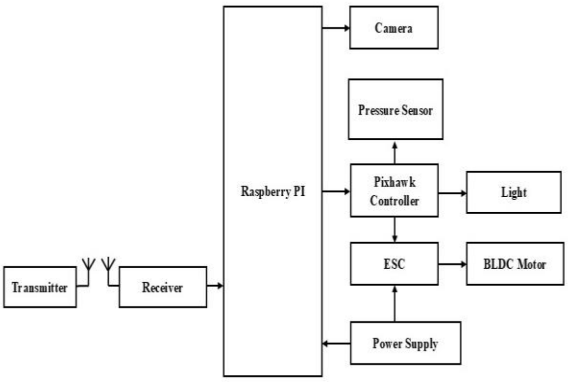

Fig 3. Block Diagram of Vehicle

V. Hardware Archeitecture

The underwater vehicle is operated by its central control system, the Raspberry Pi 4. This compact yet powerful computing module is powered through an Ethernet cable, ensuring reliable communication and energy supply. To enhance the vehicle’s capabilities, We have integrated a pressure sensor for precise depth measurement, allowing the vehicle to navigate accurately based on water pressure. Additionally, another critical component, the Pixhawk controller, has been incorporated. Together, these systems provide a robust and responsive control framework for the vehicle.

TABLE I. TECHNICAL SPECIFICATION

Components Used	***Specification***
Raspberry PI	5V
ESC	30 Amps
BLDC Motor	2200kv
Pressure Sensor	gy-ms5837 (I2C Communication)
Controller	Pixhawk

A. Raspberry Pi 4:

The Raspberry Pi is equipped with a Broadcom ARM-based processor and offers various ports, including Universal Serial Bus, High-Definition Multimedia Interface, Ethernet, and General-Purpose Input/Output pins, which makes it well-suited for connecting sensors, cameras, and additional devices. Here it is powered through ethernet tether cable and distribute required power to the camera and pixhawk. This plays the crucial part in this vehicle.[7]

B. Pressure Sensor:

The gy-ms5837 pressure sensor detects pressure to determine the vehicle's depth by using the equation

$$P = \rho g h \quad (1)$$

Where, ρ is the water density (1000 kg/m3)

g is the gravitational acceleration (9.81 m/s)

h is the depth.

P is the measured pressure.

ρ, g is known parameter and h is the parameter which we are calculating.

C. ESC:

The ESC is an essential element to determine the speed, direction of the motor and dynamic braking of electric motors. It regulates the power delivered to the motor based on control signals received from transmitter.[12]

D. Controller:

I have incorporated pixhawk based on ARM Cortex-M4 architecture with STM32F427 and STM32F100 processors. It integrates advanced sensors to provide precise control, enhanced stability, and improved maneuverability. Its Inertial Measurement Unit, featuring gyroscopes and [8][9] accelerometers, captures data on orientation, rotational speed, and linear acceleration, crucial for maintaining balance and stability during motion. A magnetometer serves as a digital compass, delivering accurate heading information essential for navigation. A barometric sensor measures atmospheric pressure, supporting altitude determination in aerial systems, while external pressure sensors can be added for underwater depth measurement.[10]

TABLE II. BODY AND FRAME SPECIFICATION

Components Used	***Specification***
Frame	PVC Pipe
Body - Acrylic Pipe	35cm
End Cap	Aluminum
Wing	FRP Sheet

Components Used	***Specification***
Dome (Camera enclosure)	Acrylic Pipe

VI. PROCESS

The vehicle is equipped with sensors and has high-definition camera designed to capture a detailed data of the hull's surface, after ensuring the sensors and whole vehicle is water resistant, it is launched into the sea from a designated area. Once it is deployed into the sea, the vehicle descends and begins its mission and navigate around the hull of the ship's surface by the commands from the person who operate it.

During this exploration, the vehicle captures the live footage which is transmitted back to the control station in real time and even stored in the storage space to access it whenever they need. This allows the operator or the inspector to monitor the condition of the hull as the onboard cameras provide a comprehensive view of the hull, enabling the detection of various forms of damage, such as corrosion, cracks, sea growth. Furthermore, if any anomalies found, the vehicle will send the exact ship location of damage to the operating person or to the control room.so we can easily proceed to the maintenance of that particular area without wasting much time.

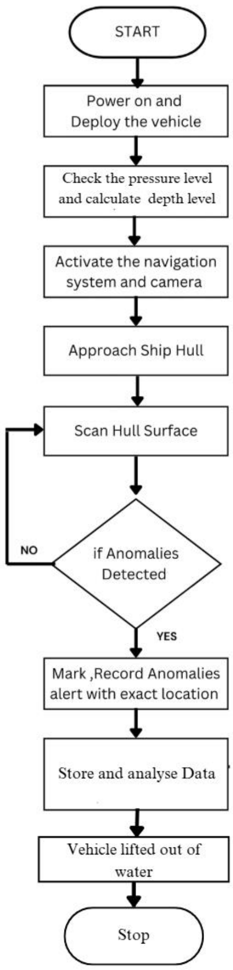

Fig 4 Flow Chart

VII. ABREVATION

ROV – Remotely Operated Vehicle

ESC – Electronic Speed Control

BLDC – Brushless Direct Current

PVC – Polyvinyl Chloride

VIII. RESULT

The implementation of underwater vehicles for ship hull damage detection using camera technology has yielded significant results, proving to be an effective, precise, and reliable method for maritime inspections. The real-time transmission of high-definition footage enables immediate assessment of the ship's hull, allowing operators to identify any anomalies or damage with clarity and speed. The vehicle's ability to access hard-to-reach areas, coupled with its autonomous navigation, ensures comprehensive coverage of the entire hull, from the keel to the rudders. Furthermore, the detection of damage is not only swift but also highly accurate, with precise geolocation data transmitted back to the control station. This allows for targeted maintenance, reducing downtime and repair costs.

- **High Precision and Detailed Data:** Equipped with high-definition cameras, the underwater vehicle captures clear, detailed images of the hull, which can reveal even minor damage like cracks, corrosion, or pitting. This ensures that small issues are identified early before they escalate into major problems.
- **Accurate Location Tracking:** If damage is detected, the vehicle can send precise GPS coordinates or location data of the affected areas to the control station
- **Reduced Inspection Time:** Underwater vehicles can complete inspections much faster than traditional methods, such as using divers or dry-docking the ship. With navigation and high-speed movement, these vehicles can cover the entire hull efficiently, significantly cutting down the time required for inspections.
- **Elimination of Mobilization Time:** Unlike diver-based inspections, which require time to prepare and safely deploy divers, underwater vehicles can be deployed almost immediately. This rapid deployment capability saves time and ensures prompt inspections, especially in emergency situations
- **Effective Streamlined Data Review:** Video footage captured during the inspection is stored in digital format (MP4), enabling fast review and analysis. This digital storage format also allows operators to quickly share the data with relevant stakeholders or maintenance teams for further action.

TABLE III Result Table

S.No	Advantages	
	Parameter	***Result***
1	Divers	Completely independent of divers
2	Data Accuracy	90% accuracy from camera
3	Delay	95%-time consumption is reduced
4	Maneuverability and Stability	High maneuverability and stability

IX. CONCLUSION

In conclusion, the development and implementation of an underwater vehicle for ship hull damage detection represent a significant advancement in maritime inspection technology. By leveraging high-definition camera systems and advanced navigation capabilities, this innovative solution facilitates thorough and efficient assessments of a vessel's structural integrity while minimizing downtime and operational disruption. The vehicle's ability to perform real-time inspections allows for immediate identification of anomalies, thereby enabling timely maintenance and reducing the risk of severe damage. Overall, this underwater vehicle exemplifies the potential for innovation to transform traditional practices in ship maintenance and inspection, paving the way for a more resilient and technologically advanced maritime future.

FUTURE SCOPE

The future scope of the underwater vehicle for detecting ship hull damage by adding sensor technology and autonomous capabilities. Enhanced sensors such as high-resolution sonar and laser systems will provide more precise detection of microcracks and corrosion. AI algorithms can enable autonomous identification and classification of defects, improving the accuracy and efficiency of inspections. Future underwater vehicle may also perform autonomous repairs, using robotic arms to fix identified hull damage.

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