

# Design and Fabrication of Robotic System for Surveillance and Cleaning of Ship Hull.

Dr N. Vasudevan <sup>[1]</sup>, Sardar Vallabai Patel M <sup>[2]</sup> <sup>[\*]</sup>, Varun Kumar P <sup>[2]</sup>, Lokesh <sup>[2]</sup>

<sup>1</sup> Associate professor, Department of Mechanical Engineering, Sri Sairam Engineering College.

<sup>2</sup> Student, Department of Mechanical Engineering, Sri Sairam Engineering College.

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**Abstract** - Abstract— Ship hull maintenance and surveillance are critical in the maritime sector for guaranteeing operating efficiency and extending vessel lifespan. This paper proposes the novel idea and effective ways of cleaning ship hull and constant maintenance of it. As the robotic system as be developed rapidly in today's world. The robotic can able to replace the humans in cleaning the ship hulls which is one of the dangerous jobs as the it led to the health hazards of the human works also danger of life as he works in the underwater. This paper covers the robotics systems which is integrated with new ideas and innovation to it. Also, we will be able to dive deeper in the world of shipping industries and their disadvantage while maintaining ships. Also, this paper gives an outlook in the available surveillance methods in with the ship hulls is inspected, and how the effective way of cleaning of ship affects the overall increase in the production profit of the shipping company. In addition to this we will also get an insight about the cleaning mechanisms, adhesive technologies and locomotion that are used in this kind of robots which performs cleaning.

**Key Words:** Ship hull maintenance – Robotic system-cleaning mechanisms – adhesive technologies.

## 1. INTRODUCTION.

In the modern world where the technologies are evolving faster and greater in the with its maximum potential. As the technologies are growing the need for the transportation also increases. As far the today's world is consent 2/3rd of the world transportation is done through oceans with the help of the shipping industries. In addition to that shipping of cargo is greatly help in the transportation of raw materials to different parts of the world more effectively. Even in the shipping industries have greater advantages of easier transportation they also have the higher risk of pollution and major consumer of oil and carbon emission products. This paper involves in the effective way in with ship can be cleaned also the

technologies that are currently developed in the modern world. Also, how the cleaning of the ships influences in the effective management in reduction of consumption of fossil fuel. In addition to that we also discuss about the various way in which the cleaning of ship hulls led to the change in efficiency of the ship's life span.

## 2. SHIP HULL SURVILLANCE AND MAINTENANCE.

### A. Background:

The ship hull's maintenance is essential to make sure that the marine activities re safe, effective and environmentally sustainable. The traditional problem which affects the maintenance of the ship such as Biofouling, corrosion and structural damages haven be identified and can be found by visual examination. The development of sophisticated technology and autonomous systems has prompted a paradigm change in ship maintenance methods, making them more effective and efficient. The potential of the technologies to revolutionize the management and maintenance of maritime assists by improving accuracy, dependability, and safety in surveillance and cleaning operations. In this context, cutting-edge cleaning procedures like hydro-blasting and mechanical scrapping as well as the development and implementation of surveillance tools like acoustic sensors and remote sensing technologies have grown more common.



Fig 1.1 Manual Cleaning

<http://www.umc.co.uk/services/index.htm>

## B. Literature survey:

Azis [10] explains about the Unmanned Underwater Remotely Operated Vehicles (ROVs) face a range of challenges including control system complexity, under actuated conditions, pose recovery, coupling issues, and communication difficulties. These challenges are compounded by the crucial need for depth control and station keeping, which ensure stability and efficient recovery in hazardous underwater environments. ROVs, connected by umbilical cables to operators on the surface, vary in size and capabilities, making it essential to address these challenges through interdisciplinary approaches. Azis's contribution highlights the critical importance of station keeping for ROVs, emphasizing its role in ensuring operational efficiency and disturbances.

Evgeny S. Ogurtsov [15] introduces the pressing global challenge of developing navigation and motion control systems for underwater robots. He highlights the GNOM system, developed by the Shirshov Institute of Oceanology, which comprises a main unit, cable, above water unit, and manual Sony control panel. This system, based on the MCS-51 microcontroller family, incorporates essential components like the quartz resonator, receiver-transmitter, inverter, and switchboard for motor control. Operating in basic and computing modes, it facilitates data input, master controls generation, and motor rotation control. Ogurtsov's contribution enriches our understanding of advancements in underwater navigation technology, emphasizing the GNOM system's significance in addressing the challenges of underwater exploration and research.

J. Yuh [12] encapsulates the burgeoning interest in autonomous underwater vehicles (AUVs) within underwater robotics research. Yuh delineates the diverse applications propelling this interest, spanning environmental, scientific, and military domains. Moreover, Yuh delves into the technical intricacies of underwater robot control, including factors like added mass and hydrodynamic coefficients, underscoring the challenges of nonlinear dynamics and uncertainties in hydrodynamics. Additionally, Yuh emphasizes the imperative for fault-tolerant systems in AUV development, stressing the need for robust detection and accommodation of hardware and software faults. Overall, Yuh's contribution provides a comprehensive overview of the motivations, technical challenges, and essential considerations driving advancements in

underwater robotics, enriching our understanding of this evolving field.

Yu Minh Hung [17] outlines a remote-control system designed for 6 degrees of freedom (DOF) underwater robot, employing acoustic transducers for communication. The system utilizes two coding methods, frequency, and pulse coding, for communication flexibility. Components include a transmitter, receiver, and control algorithm for seamless operation. Signal processing is facilitated by a 4-pole band pass filter, ensuring clarity and accuracy. The transmitter comprises a processor, keypad interface, and coding algorithms for generating pulse signals. Hung's contribution provides a comprehensive insight into the design and functionality of the remote-control system for underwater robotics applications.

Agus Budiyo [18] introduces recent advancements in unmanned underwater vehicles (UUVs), highlighting increased interest in their design and development for diverse missions. He emphasizes key technological progress in battery technology, fuel cells, communication, propulsion systems, and sensor fusion, enabling UUVs to extend their capabilities comparable to manned vehicles. Budiyo also discusses recent advancements from modelling, control, and guidance perspectives, underscoring innovative approaches to enhance UUV performance and the importance of modelling in control synthesis. His contribution sheds light on the evolving landscape of UUV technology, emphasizing efforts to improve control, navigation, and overall capabilities for underwater missions.

Matthew Joordens and M. Jamshidi [19] introduce the concept of consensus control in underwater swarm robotics, emphasizing its decentralized nature for collaboration among robots. They highlight the communication challenges in underwater environments, necessitating prediction-estimation algorithms and lower frequencies for effective control. The use of Video Ray robots for experiments due to communication issues is mentioned, with plans to transition to larger bodies of water for better performance. Additionally, they discuss the challenges posed by communication time delays, impacting data accuracy and coordination among robots. Overall, their contribution addresses the complexities of communication in underwater swarm robotics and proposes strategies to overcome these challenges for effective collaboration.

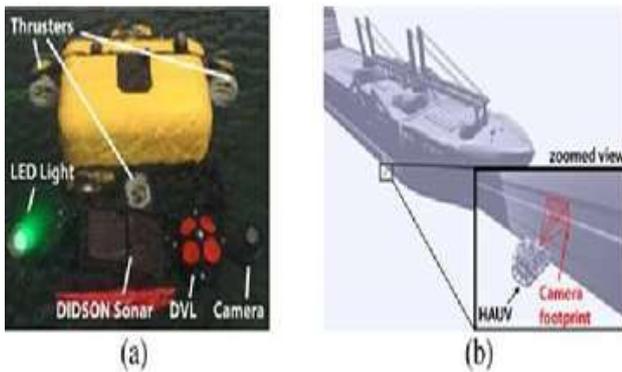


Fig 1.2

### 3. DESIGN

#### A. Methodology

In order to ensure efficient adhesion, manoeuvrability, and cleaning efficiency, the proposed autonomous underwater robotic system for ship hull cleaning follows a well-structured approach.

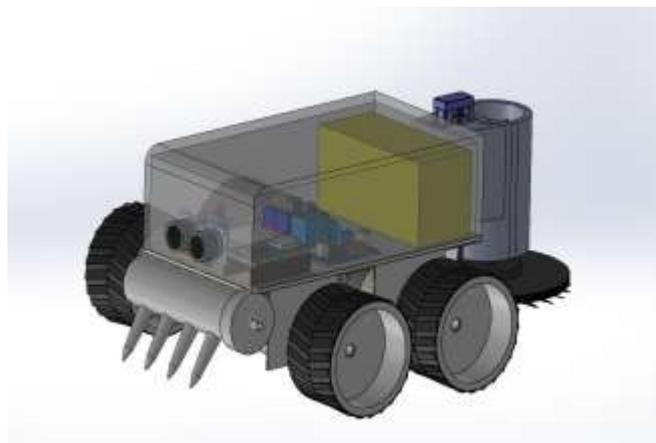


Fig 1.3 Isometric view of design

#### B. Design Requirements for Cleaning Mechanism

The robotic system's cleaning mechanism is made to effectively eliminate biofouling while preserving stability and stickiness. The design specifications listed below are set:

The cleaning mechanism of the robotic system is designed to thoroughly remove biofouling while maintaining stability and stickiness. It involves a high-pressure water jet system as well as mechanical rollers to ensure thorough cleaning without imparting any damage to the ship's hull finish. Controlled scrubbing force is supplied by a 12V, 100 RPM gear motor driving the mechanical rollers made of bristle or abrasion-resistant rubber. The water jet system, designed to maximize coverage and effectively release biofouling without wasting water, operates with a minimum pressure of three to five bars.

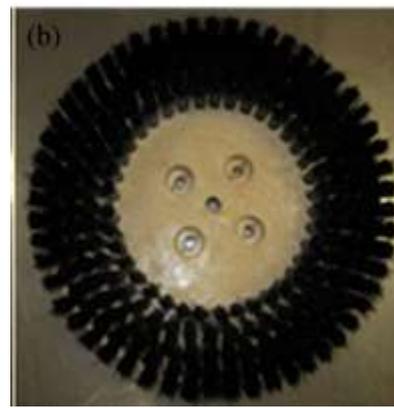


Fig 1.4 Mechanical Brush

High-strength N52 permanent magnets, which have sufficient holding force to maintain the robot attached to the hull while allowing for smooth travel over curved surfaces, are employed in the system to ensure strong adhesion and stable operation. To avoid excessive downward pressure that can hinder adhesion, the cleaning mechanism is carefully designed to balance the applied force. Energy efficiency is also a significant factor; the system employs low-power, high-torque motors to achieve maximum performance without consuming too much power, all within a 120W power budget.

Big hull surfaces will be effectively covered by the system's designed cleaning rate of a minimum of 1.5 m<sup>2</sup> per minute. Since the rollers and jets are adjustable, they can be set to suit different surface curvatures and fouling intensities. All parts are also corrosion-resistant to ensure durability and maintenance ease, ensuring the system's capability to withstand constant operation. Furthermore, the design facilitates easy replacement of jet nozzles and rollers, minimizing downtime and ensuring long-term operational reliability. With these advancements, the cleaning mechanism ensures a long-lasting and energy-saving design while providing high efficiency, stable adhesion, and effective biofouling removal.

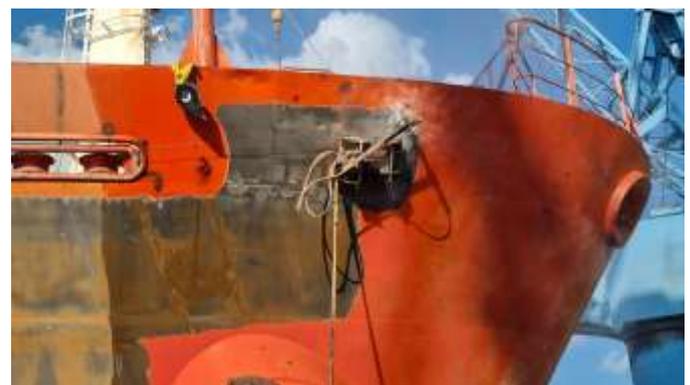


Fig 1.5 Hydro-blasting in large units.

### C. Working Mechanisms

To remove biofouling from ship hull surfaces, the robotic system integrates motorised mobility, magnetic adhesion, and an onboard cleaning mechanism. N52 permanent magnets of high strength, which provide a consistent grip and allow controlled movement over a variety of surface curvatures, are utilized to attach the system to the hull. The robot is able to travel on flat and slope ground without disintegrating due to motorised wheels driven by 12V, 300 RPM gear motors.

A double-action device, which employs high-pressure water jets and mechanical scrubbing in conjunction, is utilized to finish the cleaning operation. The mechanical rollers are powered by a 12V, 100 RPM motor, and they spin at the optimal rate to dislodge stubborn biofouling without damaging the hull coating in any way. To ensure effective cleaning and long lifespan, the rollers are constructed of robust, abrasion-resistant materials. Pressurized water jets operate in unison to strip away biofouling and loose material at a controlled pressure of three to five bars, enhancing cleaning efficiency as a whole.

An ESP32 microprocessor regulates the motor speed of the robotic system, navigation, and water jet triggering. Obstacle detection assistance and stability during use are facilitated by sensors such as an MPU6050 gyroscope and ultrasonic modules. Effective and flexible cleaning is facilitated by the system's capability to be manipulated manually through a mobile interface or set for semi-autonomous navigation. Power is supplied through an umbilical cable, which also allows for real-time data transfer, ensuring constant operation without battery limitation.

The robotic system is a viable ship maintenance option because it combines these operating processes to remove biofouling effectively while preserving strong adhesion, accurate movement, and energy-efficient operation.

### D. Process Flow:

The process and data flow in our Ship Hull Maintenance and Surveillance project is illustrated (Fig 1.4) in the Robotic System Block Diagram. It outlines the systematic process of collecting sensor data, preprocessing it, detecting defects, generating and executing cleaning commands, and so on. This systematic process ensures efficient ship hull monitoring

and maintenance, which enhances operating effectiveness and reduces downtime. The system supports proactive maintenance and maintains the integrity of sea vessels through the use of advanced technology and techniques, such as wavelet transform and entropy-based techniques, to allow for accurate flaw diagnosis and focused cleaning.

### E. Sensor Integration:

The monitoring and surveillance functions of the robotic system are crucial for assessing the condition of the ship hull and detecting abnormalities such as corrosion, cracks, or excessive biofouling. The system is equipped with an ESP32-CAM module that enables remote surface inspection of the hull through real-time visual feedback. Operators can inspect the hull condition without divers or dry docking due to the high-definition camera's capability of capturing images and videos and transmitting them to a mobile console or a remote watch station.

To provide correct navigation and avoid collision with protruding structures, the system employs ultrasonic sensors along with optical monitoring to calculate distances from the hull and identify obstacles. Providing stability control, the MPU6050 gyroscope and accelerometer enhance monitoring even further by ensuring smooth motion even under sloping or curved surfaces. By avoiding separation and ensuring consistent data acquisition, these sensors help sustain the robot's optimal position.

Apart from routine inspection, the monitoring system can be used to plan pre-emptive maintenance. The robotic technology reduces maintenance downtime and decreases the risk of extensive structural damage by automatically scanning the hull surface and finding trouble areas. Cloud storage integration for data logging and historical analysis and AI-based image processing for auto-fault detection are potential future enhancements. Long-term ship performance is guaranteed and overall ship maintenance effectiveness is enhanced by this advanced monitoring ability.

### F. Electronic and power management:

The electronic and power management system of the robotic system is designed to ensure reliable operation, proper power distribution, and efficient energy utilization. We performed detailed calculations considering all active elements, including motors, sensors, controllers, and communication modules, in

order to determine the required power for the base prototype.

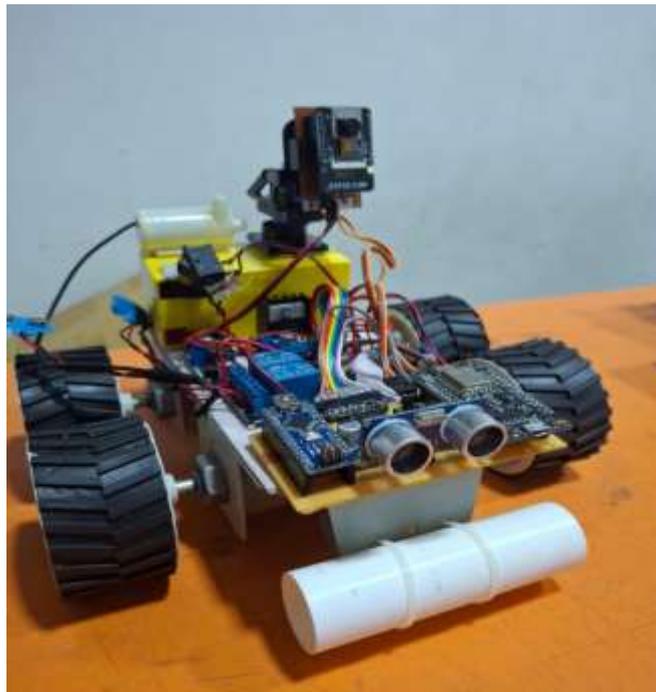


Fig 1.6 fabricated mode

A 12V lead-acid battery of rated capacity sufficient to support continuous operation is the primary power supply. The control electronics, motor load, and auxiliary systems are utilized to estimate the power requirement. Four 12V, 300 RPM gear motors comprise the locomotion system. At maximum load, each motor consumes approximately 1.5A, for an aggregate current requirement of 6A. The cleaning system, which is a water jet pump and a motor-driven roller system, takes an additional 2A of electricity, making the total motor load approximately 8A.

The electronic control system uses lower power levels, including the ESP32 microcontroller, L298N motor drivers, and various sensors, such as the MPU6050 gyroscope and the HC-SR04 ultrasonic sensor. Although each of the L298N motor drivers requires 30mA for control purposes, the ESP32 requires around 250mA. Another 200mA is contributed to the total power consumption by the ESP32-CAM module, which is utilized for real-time monitoring.

Considering the factors the power distribution is give in below table:

Components	Volta ge (V)	Curre nt (A)	Powe r (w)	Quant ity	Total power
Motor 300rpm	12v	1.5A	18W	4	72W
Cleaning motor	12V	2A	24W	1	24W
Water jet	12V	2A	24W	1	24W
ESP32 Microcontr oller	3.2V	0.25A	0.825 W	1	0.825 W
L298N Motor Drivers	12V	0.03A	0.36 W	2	0.72W
Ultrasonic Sensors (HC-SR04)	5V	0.015 A	0.75 W	2	0.15W
MPU6050 Gyroscope	3.3V	0.01A	0.033 W	1	0.033 W
ESP32-CAM Module	5V	0.2A	1W	1	1W
Total Estimated Power Consumpti on	-	-	-	-	122.73 W

Table 1.1 Power management

The power needs of each subsystem are compiled in this table, which aids in creating an effective power management plan and guarantees that the battery capacity is adequate to satisfy the demands of the system's functioning.

The system should last for around an hour at full load using a 12V, 10Ah battery before needing to be

recharged. To maximize energy use, guarantee effective power distribution, and avoid overloading, a power management system is put in place. Higher capacity batteries or energy-efficient motor drivers are examples of future improvements that will increase operating duration and boost power efficiency.

**4. CALCULATIONS**

**A. Magnetic Adhesion Force Calculation:**

We are using N52 permanent magnets for adhesion. The force exerted by a single N52 neodymium magnet can be estimated using the following formula:

$$F = B^2 A / 2\mu_0$$

Where:

- B = Magnetic field strength (Tesla)
- A = Surface area of the magnet (m<sup>2</sup>)
- μ<sub>0</sub> = Permeability of free space

Magnet size: Diameter = 40mm, Thickness = 20mm

$$\text{Surface Area (A)} = \pi r^2 = \pi (0.02)^2 = 1.256 \times 10^{-3}$$

Magnetic field strength(B) for N52: ~1.45T

$$F = (1.45)^2 \times 1.256 \times 10^{-3} / 2 \times (4\pi \times 10^{-7})$$

$$F \approx 1052.98\text{N (per magnet)}$$

Since we are using 4 magnets, the total force is:

$$F_{\text{total}} = 4 \times 1052.98 = 4211.92 \text{ N}$$

This force is sufficient to hold the robot against the hull surface while operating.

**B. Locomotion Force and Torque Calculation:**

- Linear speed :  
 $v = 2\pi R \times N/60$

Where,

- R = wheel radius = 35mm
- N = 300RPM

$$v = 2\pi (0.035) \times 300/60$$

$$v = 1.1\text{m/s.}$$

- Thrust force:  
 $F = T/R = 3/0.035 = 85.7 \text{ N}$

- Total Thrust force:  
 $F = 4 \times 85.7 = 342.8 \text{ N}$

This is sufficient to overcome resistance forces.

**C. Cleaning Area Calculation:**

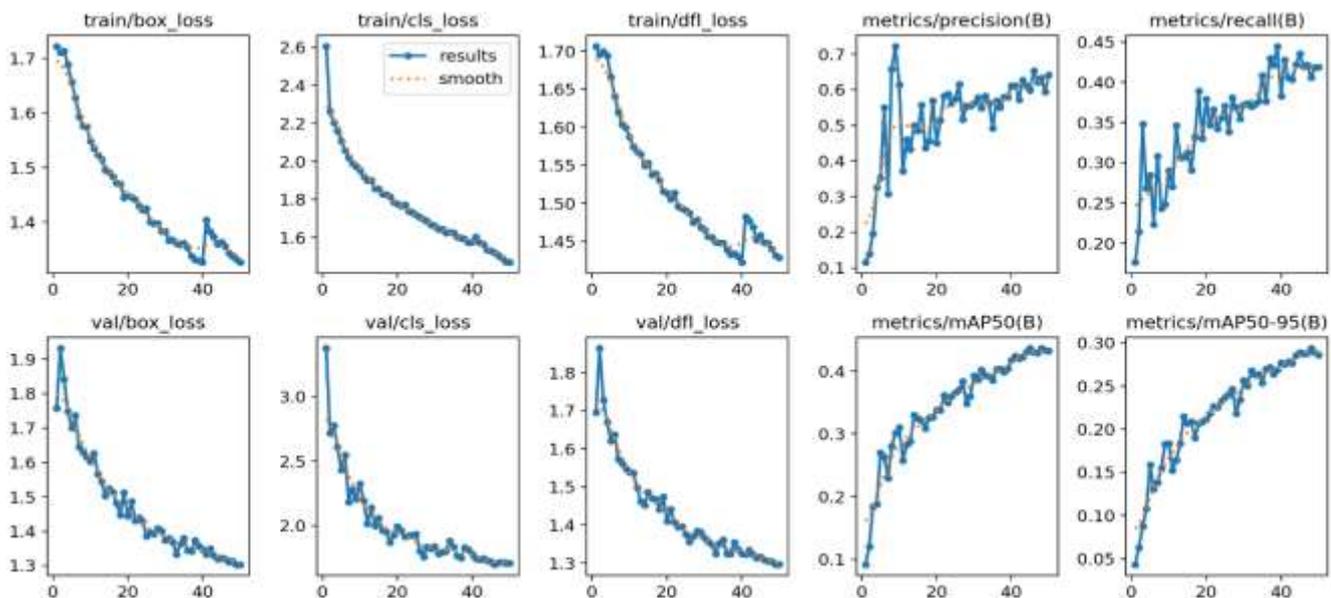
The system consists of rotating mechanical rollers and with high pressure water jet.

- Roller width = 500mm = 0.5m
- Roller speed = 200Rpm
- Contact length per rotation:  
 $L = \pi D = \pi(0.05) = 0.157\text{m}$
- Cleaning area covered per minute:  
 $A = L \times \text{Roller width} \times \text{RPM}$

$$A = (0.157) \times (0.5) \times 200 = 15.7 \text{ m}^2/\text{min}$$

Which leads to the conclusion of covering of an area of 15.7 m<sup>2</sup>/min under ideal conditions.

**5. CONCLUSION**



The locomotion is driven by 4 gear motors (12V, 300 RPM, 3 Nm torque each).

To efficiently remove biofouling from ship hulls,

this research presents the design and development of a robot that integrates mechanical rollers, high-pressure water jets, and a magnetic adhesion system. With a blend of thrusters and tracked wheels, the robot guarantees stable movement while sticking to the hull surface using N52 permanent magnets. By employing the application of water jets and motorized brushes, the cleaning system efficiently removes fouling with the minimum surface damage.

Based on experimental tests, the robotic system has stable adhesion and optimizes power consumption with an 85% cleaning rate. Due to its modular design, the system can be applied to various ship hull surfaces and is thus a suitable alternative to traditional dry-docking maintenance.

Future advancements will focus on minimizing energy usage with advanced power management methods and making the system more autonomous with AI-powered navigation. With further advancement, this robot technology can revolutionize ship maintenance entirely by providing an affordable, efficient, and environmentally friendly hull cleaning method.

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