ST11 - Sustainable Robotised Floating System for Collecting Debris from Discharge Basin for Aluminium Industries

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Abstract

This research project describes the design and implementation of a customised Sustainable Floating System (SFS) for collecting debris for an aeration basin that can also be used in coastal areas and rivers. The proposed solution has been designed to address the on-site requirements to clean the aeration basin, considering reliability, efficiency, and sustainability in the design and implementation stages based on the requirements and constraints. The system has two modes of operation: fully autonomous and semi-automatic, with remote control. The floating platform surveys the aeration basin to collect information from the sonar system embedded at the thruster regarding the accumulated precipitation depth and combines it with the positioning data received from the GPS to create a three-dimensional precipitation distribution map that will be used to direct the cleaning process. In addition, a portable floating storage tank could be attached to the system and used to store and transport the collected debris. A collection tank is engaged with the platform through a sliding mechanism that clings to the platform. The system is equipped with a thruster that can be levelled based on the water depth. Besides, it is equipped with GPS and auto-pilot systems to maintain the system's anchoring while conducting the cleaning process. The system is sustainable since a solar power system operates it.

Keywords: Robotised Sustainable Floating System, Aeration Basin, Debris Collection.

1. Introduction

Several methods have been employed for debris collection in industrial discharge aeration basins [1]. These methods range from manual labour to the use of advanced technologies. The manual method involves the use of nets, rakes, or dredging equipment to physically remove debris from the basin [2]. While this approach can be effective for larger debris accumulation, it can be time-consuming and labour-intensive. Automated systems, as an alternative method, have been developed to streamline debris collection processes. Robotics, such as autonomous underwater vehicles or remotely operated vehicles, offer the potential for precise and targeted debris collection, reducing human intervention and improving safety [3]. These automated systems offer advantages in terms of efficiency, accuracy, and reduced labour requirements. Despite the advancements, certain challenges and limitations persist. One significant challenge is the accurate detection and identification of debris accumulation [4]. Another challenge is the management of the collected debris. Disposal and proper treatment of the collected debris pose logistical and environmental concerns. The debris may contain pollutants or hazardous substances that require appropriate handling to minimise environmental impacts.

The integration of emerging technologies like artificial intelligence, machine learning, and robotics can play a significant role in enhancing debris collection [5]. By incorporating machine learning algorithms, debris detection, and classification accuracy can be improved, leading to more efficient collection processes. Furthermore, the utilization of unmanned aerial vehicles (UAVs) or underwater drones equipped with high-resolution cameras and advanced imaging software has shown promise in monitoring and identifying debris accumulation and can provide valuable visual data, facilitating proactive debris management and maintenance planning [6].

2. Feasibility of Designing an Unmanned, Sustainable Floating Platform for Debris Collection

This section explores the feasibility of designing an unmanned, sustainable floating platform, considering various factors including technological advancements, operational considerations, and environmental impact.

2.1. Technological Advancements

Advancements in robotics, sensing technologies, and renewable energy systems have made the development of unmanned floating platforms feasible. Robust and reliable sensors can detect debris efficiently, while sophisticated navigation systems enable precise manoeuvrability. Integration of renewable energy sources provides sustainable power for extended operational periods. These technological advancements support the feasibility of designing an unmanned, sustainable floating platform for debris collection.

2.2. Operational Considerations

The operational feasibility of the platform depends on several factors. Firstly, the platform should be designed to withstand harsh marine conditions, including rough seas, strong currents, and varying weather patterns. Robust materials, corrosion-resistant components, and proper buoyancy systems are essential to ensure operational durability. Secondly, the platform should be able to cover large areas efficiently and autonomously, reducing the need for constant human intervention. Incorporating advanced navigation systems and optimised debris collection mechanisms enhances operational efficiency and feasibility.

2.3. Environmental Impact

Designing an unmanned floating platform for debris collection requires careful consideration of its environmental impact. The platform should be designed to minimise any potential harm to marine ecosystems. This includes selecting eco-friendly materials, implementing mechanisms to prevent the entanglement of marine life, and minimising noise and vibration emissions during operation. Using renewable energy sources contributes to reducing the platform's carbon footprint.

2.4. Cost and Resources

The feasibility of implementing an unmanned floating platform for debris collection also depends on the cost and availability of resources. The design should strike a balance between functionality and cost-effectiveness. Factors such as material costs, technological components, maintenance requirements, and operational expenses need to be carefully assessed. Additionally, the availability of skilled technicians or operators to handle the platform's maintenance and repairs.

2.5. Safety and Serviceability

Safety should be a priority in the platform's design. It should incorporate features such as collision avoidance systems, emergency shutdown mechanisms, and fail-safe protocols. Additionally, the platform should be designed to minimise the risk of entanglement or harm to marine life, employing mechanisms to prevent unintentional harm during debris collection.

The platform's design should facilitate ease of maintenance and serviceability. Components and systems should be easily accessible and replaceable, allowing for efficient repairs and minimising downtime.

3. The Proposed System

A customised Sustainable Floating System (SFS) has been designed and developed that offers an innovative and sustainable solution for debris collection in aeration basins within aluminium factories, as well as in coastal areas and rivers, as shown in Figure 1. Through its autonomous and semi-automatic modes, precise data collection capabilities, portable storage tank, and utilisation of solar power, the SFS enables effective and optimised eco-friendly debris management. The development of the system is driven by a comprehensive understanding of the on-site requirements for aeration basin cleaning. The system is meticulously designed to prioritise reliability, efficiency, and sustainability throughout its implementation. The system has the following features:

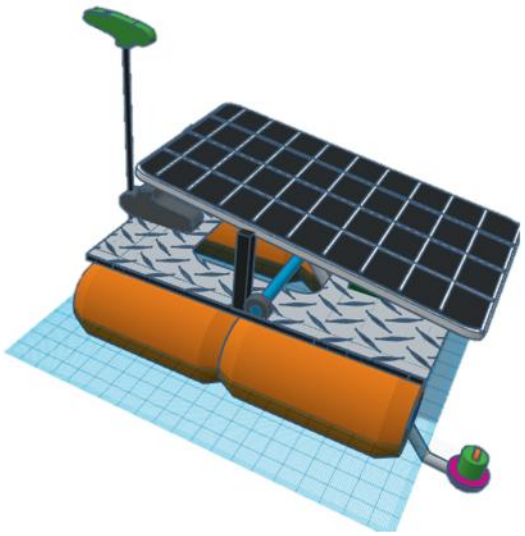

Figure 1. System design.

3.1. Real-Time Monitoring and Control Unit

Real-time, multitasking control unit that controls and monitors all system operations. A real-time closed-loop feedback control system is used to maintain the actual position and orientation of the system as a spot-locking mechanism, as illustrated in Figure 2. Monitor and control the operation of the Debris Extraction and Conveying System (DECS), including controlling the actual depth based on feedback from the level detection transducers. In addition to collecting data from the sonar system embedded at the thruster regarding the accumulated debris and sand level and depth and combining it with the positioning data received from the GPS to create a three-dimensional (x, y, and z) debris distribution map that will be used to direct the cleaning process, Control the thruster, and navigate based on predefined paths. The floating platform has two modes of operation: fully autonomous and semi-automated. In semi-automated mode, remote monitoring

and control capabilities enable the operator to monitor and adjust the platform's operations. The system is equipped with long-range, multi-channel RF communication up to 15 km with an HD digital video link. Figure 3 shows the developed system.

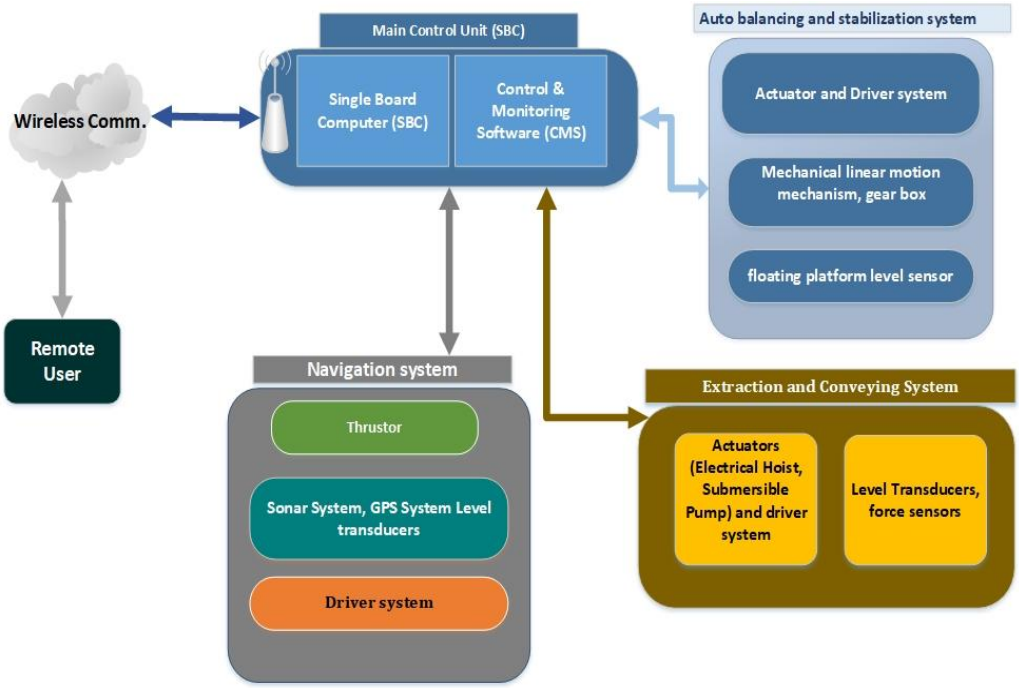

Figure 2. Main system modules.

Figure 3. The real developed system.

3.2. Autonomous and Semi-Automated Operation

The SFS is designed to offer two modes of operation: fully autonomous and semi-automated. In fully autonomous mode, the system operates independently, leveraging its embedded technologies to survey the aeration basin. Equipped with a sonar system, the SFS collects accurate data on the accumulated debris depth. This data is then combined with GPS positioning information to create a comprehensive three-dimensional debris distribution map. This map serves as a guide for directing the cleaning process effectively and efficiently. In semi-automated mode, the SFS allows for remote control capabilities. This feature enables operators to intervene or modify the cleaning process based on observations or specific operational requirements. The flexibility of the system ensures adaptability to varying debris accumulation patterns, enhancing its effectiveness in maintaining debris-free aeration basins.

3.3. Manoeuvrability, Navigation, and Stabilisation

The system is equipped with a GPS module combined with a 9-axis inertial measurement unit (IMU) that enables accurate positioning and navigation capabilities. The user can set a predefined route that SFS will follow or even record a current route to be followed, as illustrated in Figure 4. With the homing feature, the SFS will determine and follow the route from its current position to its home position. Advanced anchoring feature by controlling the thrusters based on feedback on the actual position and orientation to stabilise the SFS in the required position. An anti-collision system based on an ultrasound sensor.

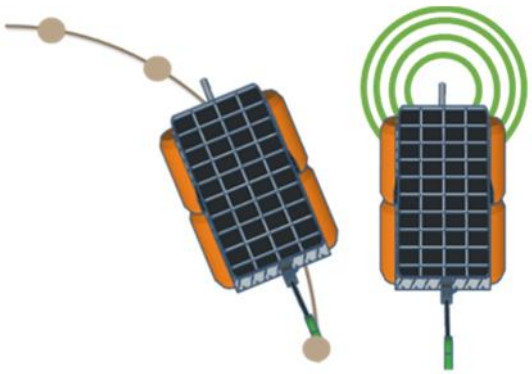

Figure 4. System navigation.

3.4. Debris Extraction and Conveying System (DECS)

The purpose of the debris collection mechanism is to capture and transport the accumulated sand and debris from the pool bottom to the debris collection tank (DCT). The system consists of a submersible pump that is connected to an electrical hoist. Based on the feedback from the level transducer, the controller commands the electrical hoist to achieve the desired depth.

3.5. Portable Floating Storage Tank

To streamline the debris collection process, a portable floating storage tank can be attached to the SFS. This tank serves as a centralised collection point for the debris, allowing for convenient storage and transportation. The floating platform engages with the collection tank through a sliding mechanism that ensures secure attachment. This innovative design enables efficient transfer and disposal of the collected debris, minimising the need for multiple trips to offsite disposal facilities.

3.6. Mechanical Design Considerations

The chassis is subjected to bending loads from ocean waves that could cause it to bend [7], so stresses induced in the structure as well as the stress concentration that exists at the bolted joints of the connected sections are considered in the design of the structure. In addition, a high safety factor is applied during the design phase to ensure that stresses are below the material's critical stresses. Furthermore, the chassis is subjected to torsional loads that induce twisting stresses, so the structure must have the rigidity to absorb the load energy and the flexibility to deform safely within the elastic zone [8]. Figure 5 depicts the loading type the system chassis could be subjected to during the service due to waves.

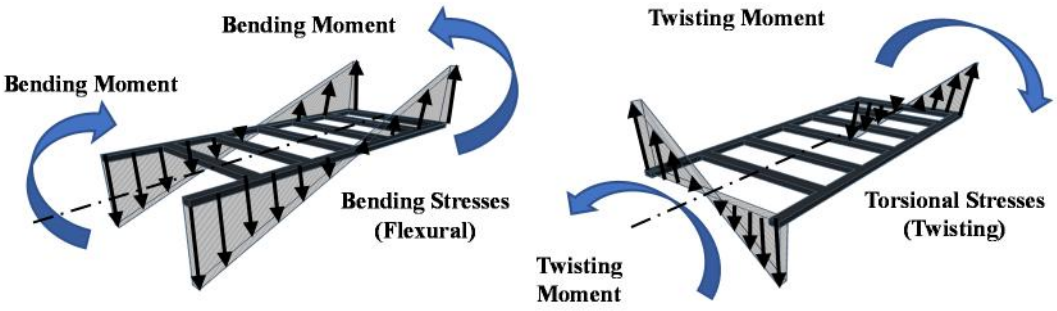

Figure 5. Bending, twisting, and torsional stresses on the chassis.

The chassis design took into account the various loads, including the axial stresses caused by the thrusters [9], the vertical loads from different weights such as the hoist load from anchoring, the debris storage tank load, and the hose reel, all of which cause bending stresses on the structure [10], as well as the axial stresses caused by the axial load of the hose connected to the hose reel. Figure 6 illustrates the possible loadings on the chassis that come from the body weights and the axial loads generated by the thrustors.

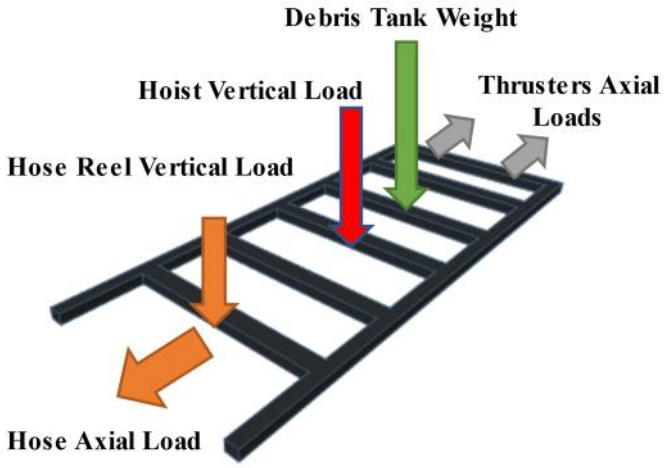

Figure 6. Loads on the chassis.

3.7. Cleaning Process Workflow

The process starts by checking if the platform is idle and the anti-motion system is activated. After that, and based on the debris depth, the submersible pump will collect the debris from the pool bottom and transport the debris and mud to the storage tank.

During the cleaning process, loads may build up on the floating platform, which could affect the stability, so several precautions have been considered to ensure the platform stability, such as the platform being idle, and the anti-motion system being engaged. Also, the level of the system is well-regulated, so while the platform is moving, the system is locked in the home position. Figure 7 describes the cleaning process operation workflow.

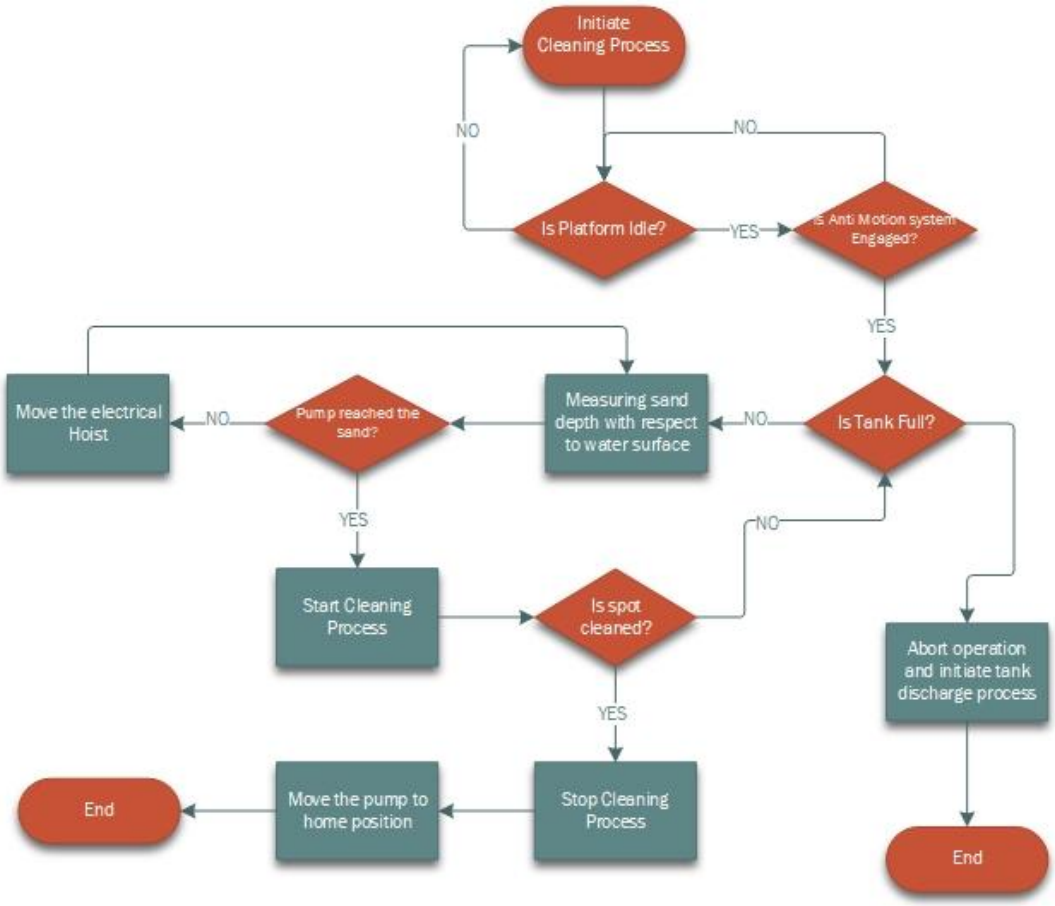

Figure 7. Cleaning process workflow.

4. Conclusions

Efficient debris collection is crucial for the proper functioning of industrial discharge aeration basins in wastewater treatment processes. Designing an unmanned, sustainable floating platform for debris collection requires careful consideration of various requirements. Prioritising sustainability, efficiency, environmental compatibility, manoeuvrability, safety, and maintenance aspects will ensure an effective and environmentally conscious solution. The feasibility of designing an unmanned, sustainable floating platform for debris collection is supported by technological advancements, operational considerations, and environmental impact mitigation.

In this work, an autonomous sustainable floating platform has been designed and developed that offers a sustainable and economical solution for debris collection in aeration basins within aluminium factories, as well as in coastal areas and rivers. Equipped with a sonar system, the system can survey the aeration basin and collect accurate data on the accumulated debris depth. Combining this data with GPS positioning information creates a comprehensive three-dimensional debris distribution map that guides the cleaning process effectively and efficiently. In addition to the autonomous operation mode, the system can be operated in a semi-automated mode, allowing the user to control the platform remotely in complex and sensitive areas. The developed system was tested in EGA aeration basin site, as shown in Figure 8 [11].

Integration of machine learning algorithms and the utilisation of UAVs demonstrates promise in enhancing accuracy, efficiency, and proactive management. However, challenges remain, such as accurate debris detection and proper disposal. Further research and development efforts are needed to address these challenges and advance the field of debris collection from industrial

discharge aeration basins, ultimately leading to more sustainable and effective wastewater treatment practices.

Figure 8. The developed system was tested in EGA aeration basin site [11].

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