International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Design and Prototype Development of Portable Trash Collector Boat for Small Stream Application

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Abstract: ***Commercially available trash collector boats are often designed in large size to cater to the high trash loading for surface water cleaning purpose. On the other hand, for small streams and drainage, the manual cleaning method is often used. This situation is undesirable since it can lead to health problem and diseases to the operator due to the number of impurities present in the water. This paper highlights a proposed design of a trash collecting boat for cleaning purposes in small area applications such as lakes, small streams and drainage. The trash collector boat is designed to be a small and automated boat capable of collecting floating solids off the water surface and store them temporarily. The trash will be manually collected at the end of the operation. The design methodology has been accomplished using engineering design method to propose a suitable design of portable trash collector boat based on commercially available design. With the aid of Autodesk Inventor 2009, a 3D representation of the trash collector boat was generated to visualize all the details regarding the trash collector boat. System fabrication will be conducted using appropriate material to ensure the efficiency of trash collector boat. Testing and analysis were conducted to evaluate the system performance, monitoring unit performance and loading capacity of the portable trash collector boat. The results found that the collector boat is capable of handling a maximum trash load of 6 kg in a single operation.***

Index Terms: Prototype design; Surface water; Trash collector boat; Waste management

I. INTRODUCTION

Water surfaces including lakes and river are among the important feature for the world. They do not only serve as water resources for humankind but also provide valuable ecosystems for varieties of flora and fauna. However, with the increasing number in urban population and growth of industries, lakes and rivers are suffering from pollution problem [1]. Floating solids including beverages can, plastic bottles, food packaging, container, straws and Styrofoam cups are among the major solid waste that can be found in the surface water [2,3]. These waste materials that are being effortlessly dumped into the water bodies and create a harmful environment to human as well as animals and plants [4,5]. The unwanted presence of these wastes in the surface water will also contribute to the environmental problems such as drain logging and flash flood as well as potential diseases such as malaria and typhoid [6]. Hence, to overcome this situation a trash collecting system for surface water was developed for the rejuvenation of water bodies.

Trash collector boat has been widely used for cleaning purposes of the water bodies. There are quite a number of commercially available collector boat including rubbish collecting system [7], Buddy [8], Water Witch [9], Cataglop [10] and Trash Hunter [11]. Most of them are designed and equipped with several functions such as scrapper and hydrocarbon separator to efficiently remove waste materials and floating solids in the waterways. However, the current design of trash collector boats is mostly focused on large area application such as river and sea [12]. The commercially available design of a trash collector boat requires a high manpower to operate the system [13]. On top of that, the large size of the trash collector boat makes it impossible to be used in cleaning small areas such as small streams and drainage [14]. Manual cleaning by hand is not an appropriate measure due to high impurities content in water bodies that may be hazardous and harmful to the operator [15].

Therefore, as a solution to this problem, a smaller size of trash collector boat has been designed to collect waste and floating solid from a narrow and small area such as small streams and drainage system. The trash collector boat was designed with an automatic conveyor system to collect the floating solids and can be remotely controlled from a distance. The prototype is also portable, user-friendly and environmentally friendly.

The objective of this study is to design and develop a prototype of a portable trash collector boat for small and narrow space application. The design of the trash collector boat was conducted using engineering design method and system analysis to determine the most suitable design. In addition, the 3D model of the proposed trash collector boat was constructed to obtain a general view of the design. The performance of the prototype was tested and evaluated to determine the effectiveness of the developed design in collecting floating solids from surface water.

II. DESIGN METHODOLOGY

The methodology for designing trash collector boat is based on the engineering design and system analysis. Particular attention is given to the available design of trash collector boat since they are the basic reference to the development of the concurrent design.

Manuscript published on 30 August 2019.
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A. Function Analysis Method

The aim of function analysis method is to establish the functions required by the trash collector boat to perform the desired task which is to collect floating solids from surface water. Fig. 1 shows how a trash collector boat should perform in the desired manner. It begins with collecting process where floating solids were collected off the water surface. Next, the collected floating solids will be stored temporarily in the storage container and lastly, the trash will be manually collected at the end of the process.

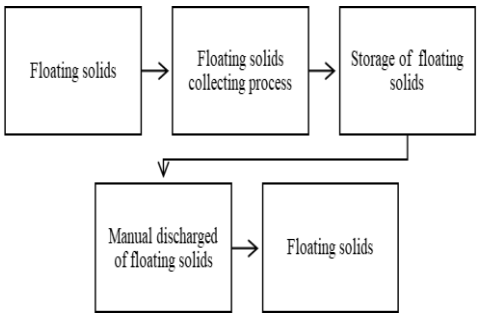

Fig. 1 Analysis of principal function for the collection of floating solids

B. Performance Specification Method

The aim of setting the performance specification is to make an accurate specification of the performance required by the trash collector boat. It is important to have the specific requirements of performance for the trash collector boat to fulfil the demand and need. The specification will only consider the most significant criteria that contribute to the performance of the system. The initial characteristic of performance requirements is summarized in Table 1.

Table. 1 Initial deduction for performance specification of trash Collector boat

Specification	Characteristic
Hull form	Catamaran
Hull material	Fiberglass
Length of boat	800 – 1200 mm
Width of boat	600 – 700 mm
Height of boat	500 – 600 mm
Maximum load capacity	3 – 6 kg
Weight	8 – 10 kg
Max speed	10 km per hour
Operation speed	10 – 20 km per hour
Boat System	Radio control
Travel distance	30 Meters
Monitoring	FPV Wi-Fi Camera, android app and battery indicator
Monitoring range	30 m
Conveyor Controlling	Relay
Conveyor controlling range	30 m

The initial deduction for performance specification was selected by considering various factors that may affect the overall performance of the collector boat. Practically, the factors involved are related to the operational environment for the system which would be the small area such as lakes, small streams and drainage. Hence, a smaller size of the collector boat as indicated by the length and width of the boat is considered in the prototype development. It is important to consider the nature of the operational environment to ensure that the system effectively operating at the working site. The trash collector boat is also expected to be lighter (approximate weight of 8 – 10 kg) for portability. The boat system is controlled by an RF transmitter and receiver which allowed the user to control the boat remotely. In addition, the incorporation of the monitoring system in trash collector boat including Wi-Fi camera, android application and the battery indicator is to ensure better monitoring of the operation of trash collector boat. Thus, the result tested of trash collector performance would be the final specification performance.

C. Quality Function Deployment Method

The aim of the quality function deployment method is to set targets to be achieved for the engineering characteristics of a product which is to satisfy the customer requirements. Trash collector boat is an alpha prototype so the function is about 75%, thus allowing the product to be used by the consumer. Nevertheless, this trash collector is not a mass production type of invention, hence it is not very popular or well-known and only recognized by a certain organization or people. Therefore, the target user for the trash collector boat can be from a small cleaning company or individual user.

D. Morphological Chart Method

The morphological chart method functions to present a complete range of alternative design solutions for a product, and hence to widen the search for potential new solutions. This method requires a list of features that are essential to the trash collector boat systems. Each feature will be compared to select the intended objective and a chart is drawn to include all the possible sub-solutions for the system. The essential generic features of a trash collector boat are as follows i) means of collecting floating solids, ii) means of storing floating solids, iii) means of discharging floating solids, iv) means of moving the boat, v) means of support to increase stability vi) means of system to assist the overall function and lastly vii) location for operator. Table 2 lists the available means for each feature of a trash collector boat based on the available design of trash collector boat. The best characteristic for trash collector boat was evaluated from the morphological chart and summarized in Table 3.

Table. 2 Morphological chart for comparison of rubbish collecting system

Feature	Means			
Collecting system	Multipurpose drop-in-pod system	Quick release system	Turbine pull system	Conveyor system

Storing System	Litter Collection basket	Skipper barge	Storage conveyor	Storage tank
Discharging system	Via crane	Via conveyor	Via pump	Via hand
Propulsion system	Fix propeller	Adjustable elevation screw propeller	Screw propeller	Propeller Paddle
Powering system	25-40 HP high thrust, 4 stroke outboard diesel engine	12V 7.2Ah Rechargeable sealed lead acid battery	Brushless motor	
Controlling system	Boat steering wheels	Radio control	Remote control	
Hull form	Catamaran	V-shape hull	Barge	Trimaran
Operator	Seated at forward	Seated at amidships	Seated at aft	Standing or sitting any where
Monitoring	Camera	Android App	Battery indicator	
Lifting	Hydraulic	Robotic	Crane	Manual by hand

Table. 3 Best characteristics for trash collector boat based on morphological chart evaluation

Feature	Means	Justification
Collecting system	Conveyor system	The system will be able to collect floating solids.
Storing system	Litter Collection basket	The system will be able to store floating solid and filtering water on floating solids.
Discharging system	Via hand	Manual handling makes the work easier to discharge floating solids from floating solids storage.
Propulsion system	Propeller Paddle	The propeller will be able to use for heavy duty and applied for slow operation.
Powering system	12V 7.2Ah Rechargeable Sealed Lead Acid Battery + Brushless motor	Efficient, reliable, long lasting and will be able to recharge.
Controlling system	Radio Control + Remote control	The system will be able to operate boat from safer grounds and at reduced levels of noise or vibration.
Hull form	Catamaran	Good stability characteristic.
Operator	Standing or sitting any where	Better vantage points.
Monitoring system	Camera + Android App + Battery indicator	The system will be able to guide the user while handling the trash Collector boat from distance.
Lifting	Manual by hand	It is because the trash Collector boat lightweight and portable.

III. DESIGN DEVELOPMENT

A. 3D Model

The design for trash collector boat for small area application was completed using Autodesk Inventor 2019 software, and a 3D model had been generated for the purpose of visualizing the requirements and specification that had been determined throughout the analysis. Four drawings are previewed with different angles of view; isometric view, front view, top view and side view as illustrated in Fig. 2.

The basic design of the trash collector boat is based on the catamaran boat with two hulls positioned at both sides of the trash collector boat. The unique feature of Catamaran hull was selected to reduce the water resistance and improve the stability of the trash collector boat. Several modifications have been made to equip the boat with an additional system for the collection of floating solids off the surface water including conveyor system and temporary storage. In this design, a rotating conveyor belt is positioned in between of the catamaran hulls along the centre line. The rotating conveyor is mounted at the front of the boat and tilted at a certain angle for an efficient trash collection system. A few of wire mesh are attached to the conveyor system to act as the main trap to collect and capture the floating solids and carried them to the storage container or dustbin that is located at the back of the trash collector boat. The dustbin is made of wire mesh web to remove any trapped water within the trash. When the dustbin is fully loaded, the boat is taken to a discharge position where the trash is manually removed into a truck or other facilities.

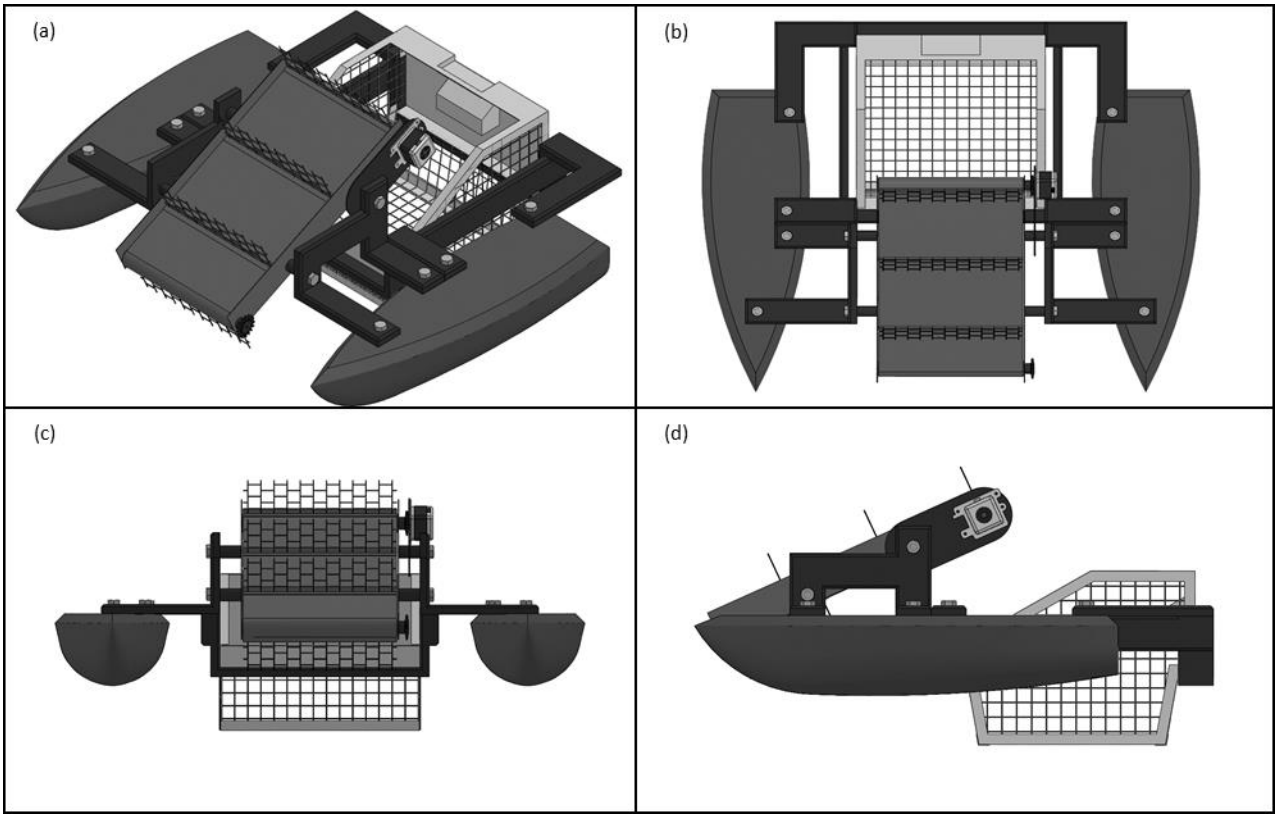

Fig. 2 (a) Isometric view (b) Top view (c) Front view and (c) Side view of trash collector boat

B. Body Fabrication

The body of the trash collector boat is divided into five main parts including frame, dustbin electronic board, hull and motor cover. Each part is built using different methods and types of materials. Every parts of the trash collector boat can be easily assembled and disassembled, except for the frame and the electronic board. Table 4 summarizes the function of each parts of trash collector boat. Several criteria were considered in the selection of materials to fulfil the objectives of the construction of a lighter collector boat. Proper selection of materials is very important to determine the right method of construction. In addition, the durability and strength of the boat are also influenced by the type of material used in the fabrication of the trash collector boat. The main body of the trash collector boat which is the frame, dustbin and conveyor system were constructed using square hollow mild steel and stainless steel net. Stainless steel was chosen since it is durable and lightweight material. On top of that, it does not corrode when in contact with water allowing their usage in the surface water. The Catamaran hull was fabricated using fibreglass material. Fibreglass is a lightweight material that is mostly used in boat fabrication [16]. It is durable and high in strength which makes it a suitable material for the hull. An electro-galvanized sheet was used in the fabrication of electronic box to store all the electronic components of the trash collector boat due to the high level of thickness which will prevent from water intrusion to the electric and electronic components of the trash collector boat. The motor cover was made using PVC material since it is durable and lightweight.

Table 4. Main components of trash collector boat

Component	Function	Material	Characteristic
Frame	• As a support to the prototype	• Square hollow mild stainless steel	• Durable • Lightweight • High strength
Dustbin	• As a temporary floating solids storage	• Stainless steel net	• Durable • Simple design • Lightweight • Easy handling
Conveyor system	• As a trash collector	• Square hollow mild stainless steel and rubber gasket	• Durable • Lightweight • High strength • Eco-friendly • Flexibility

Hull	• As a buoy to float the prototype in surface water	• Fiberglass	• Durable • Water resistance • Anti-corrosive
Electronic box	• As a storage for electronic components and power supplies	• Electro-Galvanized (E.G) sheet	• Used to keep electrical part • Higher level of thickness control • High strength • Durable
Motor Cover	• Install brushless motor	• PVC	• Durable • Lightweight • Water resistance

Table 5. Product specification and description of portable trash collector boat

Specification	Characteristic
Hull form	Catamaran
Hull material	Fiberglass
Length of boat	1143 mm
Width of boat	685 mm
Height of boat	600 mm
Maximum load capacity	6 kg
Weight	11 kg
Max speed	5 km per hour
Operation speed	10 – 20 km per hour
Boat System	Radio control
Travel distance	30 Meters
Monitoring	FPV Wi-Fi Camera, android app and battery indicator
Monitoring range	30 Meters
Conveyor controlling	Relay
Conveyor controlling range	300 Meters

C. System Fabrication

Boat system

Boat system composes of three main components including boat, remote control and adjustable step-down power supply module. It uses two motors to drive and operate the boat within 30 m distance control with 27 MHz frequency. An adjustable step-down module was used to reduce the power supply from 12 V to 7.2 V to suit the requirement of the boat system. A rechargeable sealed lead battery is used to supply power to the system.

Conveyor system

The conveyor system is the main feature for the trash collector boat to collect floating solids and debris from surface water. The conveyor system has been featured in most trash collector boat design since it can effectively collect trash and floating solid off the water surface [7,17]. The conveyor was fabricated using aluminium, gasket rubber and PVC pipe. Wire mesh was attached to the conveyor for trash collecting purpose. The system is equipped with a DC motor speed that enables the user to control the speed of the conveyor according to the collection area. In addition, a relay wireless remote control was installed into the conveyor system to allow the control of the forward and backward movement of the conveyor. The relay wireless controller can be operated within a distance of 300 m.

Monitoring System

Monitoring system consists of a camera with android application SYMA FPV and battery indicator. This system was incorporated to facilitate the operation of the prototype in terms of movement control. An FPV Wifi Camera Cam was used that supports real-time image transmission within 100 m range. It allows the user to monitor the condition of the river or the direction of the boat.

D. Testing and Analysis

The trash collector boat prototype was tested to ensure that any system and parts installed are effectively working. The monitoring system of the trash collector boat such as the camera, lamp and battery indicator was also evaluated. The product testing was completed at the university lake.

IV. PROTOTYPE EVALUATION

A. Product Specification and Description

The detailed product specification and description of trash collector boat prototype is presented in Table 5. The finished product of the prototype is shown in Fig. 3.

Fig. 3 Prototype of portable trash collector boat

B. Working Performance

System Performance

The boat system works well with the movements and speed corresponding to the collecting process of floating solids. However, the radio connection is not stable that will result in connection loss for a few times during the testing. For the conveyor system, it was found that that the rotational power is capable to hold a maximum capacity of 2 kg per rotation.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

It is limited due to the strength of wire mesh attached to the conveyor belt. Nevertheless, the speed controller and the relay of the conveyor system is working efficiently.

Monitoring Performance

The monitoring system of the trash collector boat consists of a camera, LED light and battery indicator. The camera works properly during product testing however the display quality is quite low due to the low-resolution camera (2 MP). Further improvement should be considered to improve the quality of the image for better monitoring of the trash collector boat. On the other hand, the LED light attached to the collector boat works properly. The brightness of the LED light is sufficiently illuminating the front area of the boat during the trash collection process. Battery indicator works properly by showing the digital numbers and displaying the amount of battery left. The battery indicator is visible on android application from the camera because it located in front of the camera.

C. Loading Capacity

The loading capacity of the trash collector boat prototype was investigated by inspection of water displacement level during operation. Fig. 4 shows the water displacement level of trash collector boat during the product testing in the university lake. Before any trash loading as shown in Fig. 4(a), the water displacement level is quite low indicating that the hulls are capable to accommodate the weight of trash collector in water. Fig. 3(b) shows the water displacement level after full loading of trash in the dustbin. The trash collector boat can achieve a maximum loading capacity of 6 kg in a single operation. From observation, there is a slight increment in the water displacement level when compared to before loading. The hulls are capable to hold the weight of both collector boat and trash without being sunk. This show the good performance of trash collector boat in full load mode.

Fig. 4 Water displacement level of trash collector boat (a) Before loading (b) After full load

V. CONCLUSION

This study has successfully developed a prototype of a trash collector boat. The collector boat is small in size compared to available trash collector boat in the market and suitable for small and narrow space cleaning purpose. The trash collector boat was equipped with a rotating conveyor system and monitoring system that can be remotely controlled from afar. Performance test that has been done showed that the collector boat efficiently collected up to 6 kg of floating solid in a single operation. This indicates the good performance of trash collector boat in cleaning water surface. The use of this trash collector boat can reduce the water pollution in small streams and drain clogging problem in an environmental-friendly and user-friendly manner.

ACKNOWLEDGMENT

The authors would like to thank all the faculty staff and member that provide help and assistance throughout the project completion.

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