Floating oil skimmer design using rotary disc method

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Abstract. Over the past few years there have been many oil accidents that have occurred in the sea. Oil accidents can occur due to oil spill, drilling processes at sea or due to pipeline leaks. The oil in the sea will float and if not remove will damage the surrounding ecosystem. Therefore, in this paper implements an oil skimmer system which can be used to remove and separate oil from the water. The oil skimmer system is composed of a rotary disc to take oil on the surface of the water and two propellers to move the oil skimmer. The rotary disc and propeller are driven by DC motor which is connected to the motor driver and Arduino Mega as a controller. The oil skimmer is also equipped with a joystick that is used to adjust the rotation speed of the rotary disc and control the movement of the oil skimmer. Based on the results of testing the oil skimmer has been able to take and separate oil on the surface of the water with separation speed of 620.28 ml/min at a speed of 18 rpm.

1. Introduction

Indonesia is a maritime country and is one of the oil and gas producing countries. The oil and gas produced has the potential to pollute the environment when oil spill occur. Oil spills often occur during the process of moving goods on board, drilling, and due to leakage in oil pipelines [1]. An example is the oil spill that occurred in Cilacap, Central Java. In the period 1989 to 2015, there were 17 cases of oil spill, of which 13 cases were caused by ship accidents and 4 of them were caused by pipe leaks [2]. Oil spills can also occur because Indonesia is the oil trade lanes in Southeast Asia. This condition is supported by the high shipping activity of Japanese ships around 90% and Chinese ships around 70-90% [3].

Pollution from oil spills in the sea is the focus of attention of the wider community. Oil spills in the waters will be very easy to spread and move to other places because of the influence of waves, wind, and sea water flow [4]. the impact will be very fast and threaten the survival of the organism, damage to the ecosystem, and a decrease in economic quality due to the damaged environment [5,6]. Therefore, up to now efforts to reduce, separate, and eliminate oil spills on the surface of the water are still being studied. Several methods have been developed including burning, sinking, dispersing, sorbing, biodegradation, gelling, and skimming [7]. Of these methods, skimming is the most widely used method because it is simple, easy, and does not require additional chemicals so it will be environmentally friendly [8].

The working principle of the oil skimmer is to utilize a rotating element to separate water and oil. The oil that floats on the surface of the water will then stick to the rotating element due to a force called the adhesion force. The attached oil is then separated using an element called a scraper and will flow

into the storage tank [9]. Rotating elements which until now have been developed in the form of drums, belts or discs [10-12].

This paper constructs an oil skimmer which is designed to float above the water surface. Oil skimmer is composed of a rotary disc that can rotate and function to take and separate oil spills that are above water. Rotary disc is chosen because this type is the most suitable for cleaning / taking oil with medium viscosity. Besides this type is also the most likely to be used in offshore operations [13]. Furthermore, oil skimmer is equipped with two propellers that function as a tool to drive the oil skimmer engine. The propeller and rotary disc are rotated using a DC motor connected to the motor driver and Arduino Mega 2560 as the controller. In addition, the rotary disc speed and movement of the oil skimmer can be adjusted using a joystick connected to the Arduino Mega.

2. Materials and methods

2.1. Block diagram of oil skimmer

Oil skimmer system consists of battery, rotary encoder, joystick, Arduino Mega, three DC motors and drivers, two propellers, rotary disc, and LCD. A battery in this skimmer is used to supply power to the Arduino Mega and drive three DC motors. Two DC motor are connected to the propeller. When propeller rotate in the clockwise direction oil skimmer moves in right direction but when propeller rotate in anticlockwise direction oil skimmer moves in left direction. The third DC motor is connected to a rotary disc that functions to attract and separate the spilled oil. All three DC motor are connected to the motor driver and Arduino Mega and speed and direction of rotation of the motor can be controlled using a joystick. In this oil skimmer, the speed of the rotary disc can be determined using rotary encoder method and then displayed on an LCD.

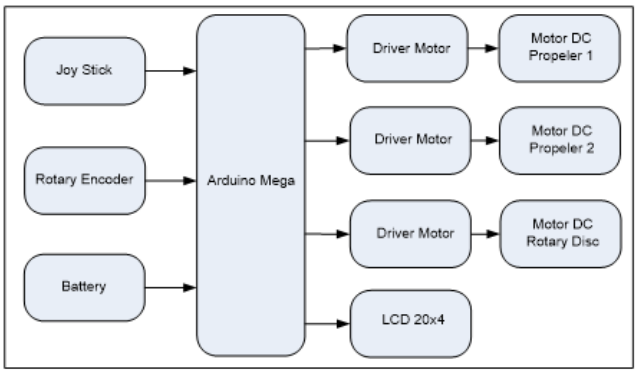

Figure 1. Block diagram of oil skimmer by using rotary disc method.

2.2. Design and fabrication of rotary disc

One of the characteristics that must be present in the rotating element in the oil skimmer is the oleophilic properties. By utilizing these properties, the oil spill will stick to the rotating element directly [14]. Yadav *et al*. (2019) have conducted experiments using oil skimmers by comparing rotary discs made of mild steals and acrylic. The number of discs in the oil skimmer is one disk with a diameter of 200 mm [9].

Following up on research results obtained by Yadav *et al.* then in this study, we used acrylic with a diameter of 60 mm and a thickness of 5 mm as a rotary disc. The diameter of the rotary disc in this paper is designed to be smaller than that previously made by other researchers (three times smaller than that made by Yadav *et al*. The aim is that this oil skimmer can be used to clean oil in deep and shallow waters. Instead we increased the number of disks in the oil skimmer to 3 disks. The rotary disc is equipped with a scraper to remove oil from the acrylic. The scraper is made of sponge and the area of

rotary disc affected by the scraper is 5600 mm^2. Figure 2a shows the design of the rotary disc used in this experiment.

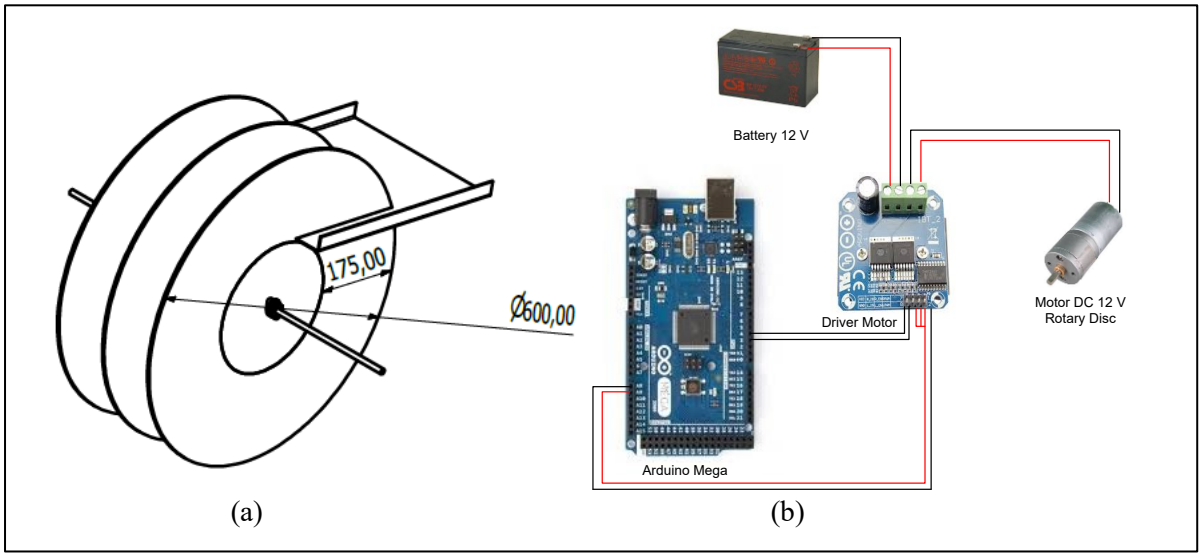

Figure 2. a) Design of rotary disc, b) Drive circuit of the rotary disc.

The configuration of Arduino Mega and the motor driver can be seen in Table 1. A voltage of 12 V enters to DC motor connected by the rotary disc set using Arduino Mega.

Table 1. Arduino Mega pin with rotary disc motor driver configuration.

Arduino Mega	Motor Driver
Vcc	Vcc
Gnd	Gnd
Pin 2	Rpwm
Pin 3	Lpwm
Vcc	L_en
Vcc	R_en

2.3. Rotary encoder circuit design

Rotary encoder is used to determine the speed of the rotary disc. The rotary encoder sensor is connected to the Arduino Mega as a data processor, then the Arduino result are displayed on a 20×4-character LCD. For the Arduino Mega pin with rotary encoder sensor and LCD can be seen in Table 2.

Table 2. The configuration of arduino mega pin, rotary encoder, and LCD.

Arduino Mega	Rotary encoder	I2C LCD 20×4
Vcc	Vcc	Vcc
Gnd	Gnd	Gnd
Pin 31	DO	-
Sda0	-	Sda
Scl0	-	Scl

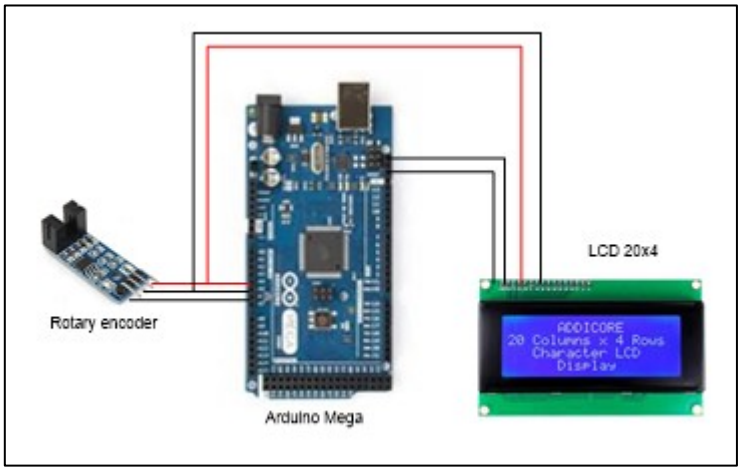

Figure 3. Rotary encoder circuit.

2.4. Design and fabrication of float

The float of oil skimmer is made of PVC (Polyvinyl Chloride) pipe which has a diameter of 5 inches. The float has a length of 1300 mm and a width of 1370 mm. The design of float in this experiment is shown in Figure 4.

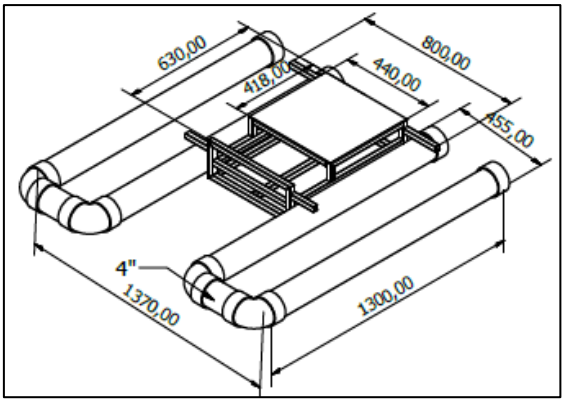

Figure 4. Float design.

2.5. Design and fabrication of oil skimmer engine propellers

The design of the oil skimmer engine is shown in Figure 5a. The propeller used is made of acrylic with a 300 mm diameter. Oil skimmer propeller mounted on the right and left of the oil skimmer engine. Furthermore, A Voltage of 12 V is used to drive each DC motor.

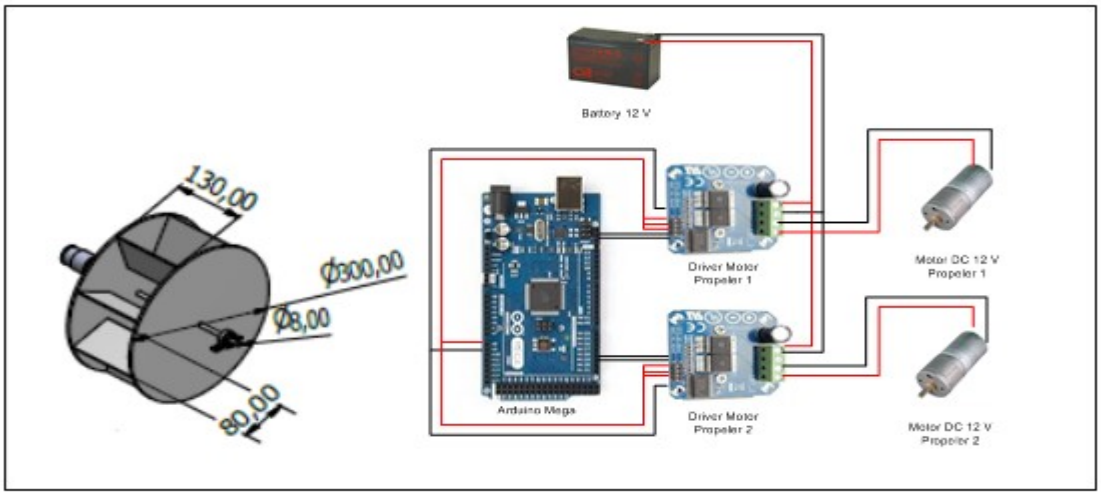

Figure 5. a) Propeller design b) Propeller drive circuit.

The DC motor rotation is controlled by Arduino Mega using motor driver. The motor driver used in this paper is BTS7960 High Current Motor Driver. This type was chosen because the motor driver can be used for higher currents (maximum 43 A) and is equipped with thermal over current. Arduino pin and motor driver connection configurations can be seen in Table 3.

Table 3. Configuration of the Arduino Mega pin and propeller motor driver.

Arduino Mega	Driver motor propeler 1	Driver Motor Propeler 2
Vcc	Vcc, R_en, L_en	Vcc, R_en, L_en
Gnd	Gnd	Gnd
Pin 4	Rpwm	-
Pin 5	Lpwm	-
Pin 6	-	Rpwm
Pin 7	-	Lpwm

2.6. Joystick and arduino circuit design

The joystick is used by the oil skimmer operator to adjust the direction of movement of the oil skimmer machine and to adjust the speed of the rotary disc. Movement of oil skimmer in the form of forward, backward, turn right, and turn left. The movement of the oil skimmer is regulated by moving the right and left propellers on the oil skimmer. The connection configuration between the Arduino pin and the wireless joystick can be seen in Table 4.

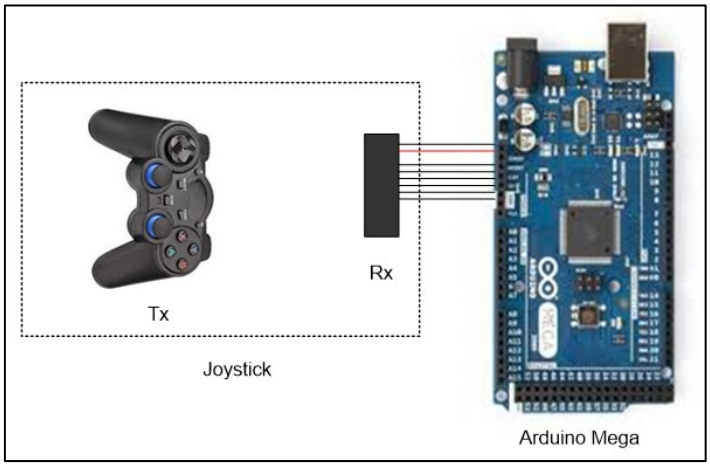

Figure 6. The joystick and arduino mega circuit.

Table 4. Configure the arduino mega pin with wireless joystick.

Arduino Mega	Joystick
Vcc	Vcc
Gnd	Gnd
Pin 10	Att
Pin 11	Data
Pin 12	Command
Pin 13	Clock

2.7. Model and implementation

Figure 7a shows the dimensions of the oil skimmer constructed in this paper and Oil skimmers in the artificial pond can be seen in Figure 7b.

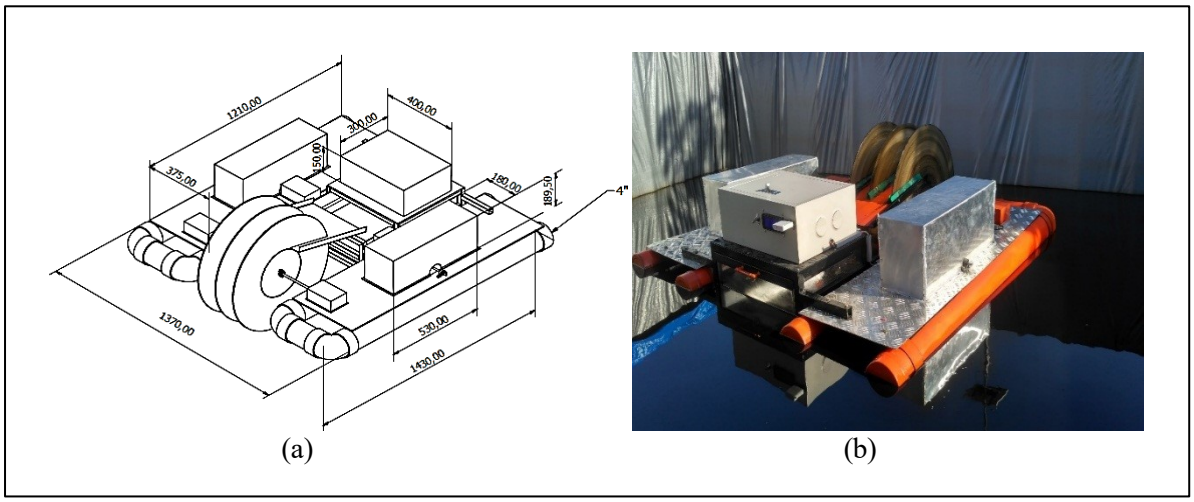

Figure 7. a) Dimension of oil skimmer b) Oil skimmer in the artificial pond.

3. Results and discussions

To make sure the oil skimmer can separate the oil spill or not, a test is conducted. The test is carried out using an artificial pond filled with water added to oil. After the oil has spread, the oil skimmer is inserted into the artificial pond. There are two things examined in this paper, namely testing whether oil can be

separated or not and determining the effect of rotary disc speed on the volume of oil taken. 4800 litre of water and 30 litre of oil were put into artificial pond. The first test was carried out using a rotary disc with speed of 14 rpm. The data is taken 5 times for the same speed to get the average speed of the volume of oil taken by the oil skimmer. Table 5 shows the results of the oil skimmer testing at the rotary disc speed of 14 rpm. The volume of oil collected in five consecutive trials was 1547, 1506, 1760, 2140, and 2136 ml. When testing the battery voltage in good condition which is 12 volts. Therefore, it can be concluded that at the time of data collection, all components used in the oil skimmer are supplied with the same voltage. From the data of oil volume taken, the average speed of oil extraction in every minute is 363.60 ml/min.

Table 5. The result of the oil skimmer test at 14 rpm rotary disc speed.

No	Amount of oil collected (ml)	Battery voltage (Volt)	Speed of oil collection (ml/minutes)
1	1547	12.79	309.4
2	1506	12.62	301.2
3	1760	12.69	352.0
4	2140	12.66	428.0
5	2136	12.32	427.2
Average	1817.8	12.62	363.56

Table 6. The result of the oil skimmer test at 16 rpm rotary disc speed.

No	Amount of oil collected (ml)	Battery voltage (Volt)	Speed of oil collection (ml/minutes)
1	2231	12.16	446.2
2	2520	12.06	504.0
3	2442	13.29	488.4
4	2455	13.01	491.0
5	2640	12.92	528.0
Average	2457.6	12.69	491.52

Table 7. The result of the oil skimmer test at 18 rpm rotary disc speed.

No	Amount of oil collected (ml)	Battery voltage (Volt)	Speed of oil collection (ml/minutes)
1	3247	12.77	649.4
2	3325	12.62	665.0
3	2851	12.52	570.2
4	3234	12.41	646.8
5	2850	12.80	570.0
Average	3101.4	12.62	620.28

The second test is testing to determine the effect of the rotary disc speed on the amount of oil collected. by doing the same steps, the test is carried out at a rotary disc speed of 16 rpm and 18 rpm. The complete results of the experiment are shown in Tables 6 and 7. The speed of the rotary disc is proven to affect the volume of oil collected. That is evidenced by the difference in volume collected at each speed. The volume of oil collected at speeds of 14 rpm, 16 rpm and 18 rpm are 1817.8, 2457.6, 3101.4, respectively. the higher the rotary speed, the higher the amount of oil collected and the speed of collection. The best performance of the oil skimmer at a rotary disc speed of 18 rpm with a speed of 620.28 ml/min.

When compared with the results of other studies, increasing the number of disks in the oil skimmer is quite effective in cleaning up oil spills. In this study, at a speed of 18 rpm the oil skimmer collected 3101.4 ml of oil (uses 3 discs). the results of previous studies, at a speed of 20 rpm oil skimmer collected 444.2 ml of oil (uses 1 disc) [3]. Therefore, the method used in this paper is very effective. In addition to increasing the amount of oil collected, the time of collection of oil is also getting faster.

4. Conclusions

The oil skimmer floating on the surface of the water has been successfully constructed. Based on the test results, the constructed oil skimmer can float and can be used to separate oil from the surface of the water. From the three rotary disc rotational speeds, it is found that the best performance of the oil skimmer is when the rotary disc speed is 18 rpm with a separation speed of 620.28 ml/min.

5. References

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