Analysis of effectiveness of oil spill recovery using disc-type oil skimmer at laboratory scale

N Widiaksana, A A Yudiana and Y S Nugroho

Fire Safety Engineering Research Group, Department of Mechanical Engineering, Universitas Indonesia.

E-mail: yulianto.nugroho@ui.ac.id,

Abstract. During the past 40 years, there have been 14 major accidents of oil spill in Indonesia, mostly as results of ship collisions. There are several methods in handling oil spill accident, in which the most effective methods are using mechanical oil skimmer with disc plate. The effectiveness of the oil skimmer on handling oil spills is influenced by various factors, such as the depth of the disk submerged or the disk surface area dipped into the oil spill, the area of the wiper sweep, the thickness of the oil on the disk surface, and the rotation speed of the disk. This paper presents the results of laboratory scale experiment of mechanical oil skimmer. The oil samples used are diesel engine oil with 15W-40 SAE and the water sample used is sea water. The experiment was conducted with variation of 27 mm and 55 mm of disc submersion depth or equal to dipped surface area of 31.35 cm$^2$ and 88,832 cm$^2$. The duration of the test for 3 data is 5 minutes. Based on theoretical calculations, the increase of rotation speed of the disk, the result of spill transport will also be higher. This is proved by the experimental results. The lifting process of oil spill is more effective with low rotation speed, because the result of oil spill transported will be more dominated by oil than water. In this test, the higher the rotation speed of the disk, the higher the water produced.

1.Introduction

Indonesia as a producer of Oil and Gas, also has the potential to contribute to environmental pollution in the form of oil spills as a result of oil and gas transportation process to and from Indonesia. According to data from the Ministry of ESDM, there are at least 14 large oil spill cases occurring in Indonesian waters since 1975 to 2009. One of the recorded accident was montera oil spills on Timor sea at 2009 which record 27,500 tons oil losses. Based on South East Asia oil trading lines, Indonesian water area in Malacca Strait, Lombok Strait, and Makassar strait are highly threatened by potential occurrence of sea pollution as a result of spilled oil by tanker or vessel collision. This condition also supported by high shipping activities from Japanese vessel for about 90% and Chinese vessel for about 70-90 % [1].

However, due to numerous accident of water pollution due to oil spill occurrence, counter action should be taken. Methods to counter oil spill are various, there are: Burning, Sinking, Dispersing, Sorbing, Biodegradation, Gelling, and Skimming [2]. Skimming method is known for its environmental friendly features, in which this method works mechanically to recover spilled oil on polluted area using its skimmer devices. There are two types of skimmer, Oleophilic Skimmer and Non-Oleophilic Skimmer, with each of them posing its own advantages and disadvantages [3].
This research is intended to study on working effectiveness of oil disc skimmer by conducting research of this custom-made oil spill recovery device in laboratory scale.

2. Methodology

2.1. Data Gathering
In order to test disc type oil skimmer working effectiveness, several methods will be applied, those test variables are depth of disc in liquid, area (slope of wiper) of wiped zone on disc, and disc rotation speed. These methods are shown in table 1. Each test will have 3 sets with each set consume 5 minutes for every take. Type of oil that will be used are Diesel Oil Lubricant with SAE 15W-40 produce by Fastron, and will be pour into sea water that will be placed into a vessel with certain amounts.

| Wiped Area/Wiper Slope Area | Values          |
|-----------------------------|-----------------|
| Depth of Disc               |                 |
| Disc Rotation Speed         |                 |

Table 1. Data Variables

2.2. Test Schematic

2.2.1. Experiment Devices. Component of experiment devices consist of this following item:
1. Disc Type Oil Skimmer
   As shown by figure 1, this is the assembly of disc type oil skimmer that will be used in this experiment, moreover this device also considered as the main item for this experiment.

   Figure 1. Disc Type Oil Skimmer [4].

In this experiment, the dimension of water tub is 320 mm x 215 mm x 150 mm. This equipment will be filled with certain amount of water in order to duplicate the actual condition where oil spill occurs, also this is intended to get easier way to measure water and oil ratio.

2. Measuring Cylinder
   This equipment will be used to measure mixture of oil and water recovered by oil skimmer.
3. Digital Tachometer
   Works to measure rotation speed at disc of the oil skimmer during data gathering.
4. Diesel Engine Lubricant (Fastron SAE 15W-40)
This lubricant used as replacement of crude oil. In every set of test, the amount of oil poured into water vessel is 200 ml.

2.2.2. Procedure of Test Preparation. Before experiment being conducted, there are few things that have to be set up. These procedures are intended to make data gathering save and not consuming too much time. The procedure are as follow: First, we have to fill water tub with mixture of water and oil using ratio off 7500 ml : 200 ml and 9000 ml : 200 ml. next we have to calibrate every measuring devices before we start the experiment. Ex: Digital Tachometer and volt regulator. Do not forget to use body protection, such as: hand gloves, shoes, and mouth cover. Place water tub below working desk and ensure that disc have been dipped into water. Prepare measuring cylinder as collecting vessel for recovered oil spill.

2.2.3 Procedure of experiment. After completing procedure written on subsubsection 2.2.2, experiment proceeded into data gathering followed by this instruction: First, Set-up the rotation according to the variation of the desired rotation. Then, pour the seawater and oil into the water bath with a predetermined ratio. Finally, conducting testing with variations that have been determined before. For data gathering, we have to recording rounds of discs every minute. The experiment was conducted for 5 minutes in one experimental variation. Recording the results of oil spill haul contained in measuring cups. Repeat the instruction for desired variations.

3. Results and Discussion

3.1. Theoretical Calculation

Theoretical calculation will be used to identify amount of oil can be recover using disc type oil skimmer. This calculation consists of several components, depth/area of dipped disc, disc rotation, test duration, and oil thickness. Thus, such components can be expressed in form of following formula:

\[
Amount\ of\ recovered\ oil\ spill = Area \times rotation\ speed \times time \times oil\ thickness
\]

(1)

Where:
Area : depth/area of dipped disc
Rotation speed : Disc rotation (RPM)
Time : Duration taken during each test
Thickness : Oil thickness (cm)

According to equation (1), area described as surface of disc that dipped into water solution and when the disc rotates several amounts of oil stick to the surface, then this area filled with oil can be wipe using wiper devices. There are three type rotation speeds: low speed, medium speed, and high speed. Duration of test of each session takes 5 minutes. We assumed oil thickness at surface of the disc will be around 0,5 mm. The result of theoretical calculation is shown in Table 2.

| Area (cm²) | Rotation Speed (RPM) | Total recovered oil (ml) |
|-----------|----------------------|-------------------------|
| 31.5      | 20                   | 157.6                   |
|           | 40                   | 315                     |
|           | 55                   | 433                     |
| 89        | 20                   | 444.2                   |
|           | 40                   | 888.8                   |
|           | 55                   | 1221                    |
According to table 2 above, we can conclude when higher rotation speed applied will result in greater number of oil being recovered. This also applies when surface area is greater. Therefore, theoretically this would produce higher efficiency.

3.2 Result of Devices Experiment

3.2.1. Oil Spill Recovery for 27 mm disc depth. In this part of experiment, there are 2 identified surface areas that used. The first one is using 90.5 cm$^2$ or 37° of wiper angle of slope. The second variation is 139 cm$^2$ or 18° of wiper angle of slope. Based on those two variables, we produce this result:

3.2.1.1. Surface area of 9046.46 mm$^2$/ wiper angle of slope 37°

![Figure 2. Result of oil spill recovered using surface area of 90.5 cm$^2$/ wiper angle of slope 37° with 3 variations of speed [4]](image)

Based on the result of the test, there are significant decreases in number of oil recovered when medium speed being applied. According to figure 2, when low rotation speed (12 RPM) being applied number of oil being recovered is 182 ml, this is the highest amount if we compare to medium speed rotation (30.5 RPM) and high-speed rotation (48 RPM) which each of them produce 92 ml and 145 ml respectively.

3.2.1.2. Surface area of 139 cm$^2$/ wiper angle of slope 18°

![Figure 3. Result of oil spill recovered using surface area of 139 cm$^2$/ wiper angle of slope 18° with 3 variations of speed [4]](image)
As shown in figure 3, when medium speed applied on disc depth of 27 mm there will be a decrease of recovered oil for wiper slope of 18° with recorded amount of 145 ml, this condition is similar to application of 37°. The decrease of recovered oil will be cause by several factors such as wiper error which lead to ineffectiveness of separating oil and water from the disc. If we compare to theoretical analysis, then we can conclude that there is a significant different result of the character from recovered oil amount based on type of rotational speed that used, since theoretical analysis implies that whenever the speed goes higher may increase amount of oil being recovered. On the other hand, based on experimental test the increasing of recovered oil only occurs when rotational speed is low.

3.2.2. Oil Spill Recovery for 55 mm disc depth. In this part of experiment, there are 2 identified surface area that used. The first one is using 90.5 cm² or 37° of wiper angle of slope. The second variation is 139 cm² or 18° of wiper angle of slope. Based on those two variables, we produce this result:

3.2.2.1. Surface area of 90.5 cm²/ wiper angle of slope 37°

![Figure 4](image1.png)

Figure 4. Result of oil spill recovered using surface area of 90.5 cm² / wiper angle of slope 37° with 3 variations of speed [4]

Based on the result of the test, there are significant increases in number of oil recovered when variety of speed being applied for 55 mm disc depth. In this variation, the characteristic of recovered oil is increasing gradually, parallel to the increasing of rotational speed. According to figure 4, when low rotation speed (12 RPM) being applied number of oil being recovered is 155 ml, for medium rotation speed (32 RPM) number of oil being recovered is 255 ml, and for high rotation speed (50 RPM) number of oil being recovered is 301 ml.

3.2.2.2. Surface area of 139 cm²/ wiper angle of slope 18°

![Figure 5](image2.png)

Figure 5. Result of oil spill recovered using surface area of 139 cm² / wiper angle of slope 18° with 3 variations of speed [4]
Based on the result of the test, there are significant increases in number of oil recovered when variety of speed being applied for 55 mm disc depth. In this variation, the characteristic of recovered oil is increasing gradually, parallel to the increasing of rotational speed. According to figure 5, when low rotation speed (17.5 RPM) being applied number of oil being recovered is 169 ml, for medium rotation speed (32 RPM) number of oil being recovered is 259 ml, and for high rotation speed (46 RPM) number of oil being recovered is 292 ml.

4. Conclusions
When 27 mm depth being applied, will produce area of $31.5 \, \text{cm}^2$ and for 55 mm depth being applied will produce area of $89 \, \text{cm}^2$. Based on theoretical calculation, if we apply larger area will produce higher amount oil being recovered. If higher rotation speed being applied, the quality of recovered solution will mostly consist with water. This condition can be proofed only with oil skimmer experiment test. Based on experiment data, slope angle of wiper or wiped area will not affect the amount of recovered oil. Since, when rotating oil will not covering every wiped area as an effect of tangential speed, so the oil tends to gather at the tip of the disc. In order to gain higher amount of recovered oil, it is necessary to consider the depth of disc on the water. If possible, the depth of dipped disc should reach its own radius [4].

5. Acknowledgment
This research is funded by PITTA from Universitas Indonesia. Thank you are delivered to Department of Mechanical Engineering - Universitas Indonesia, Mechanical Engineering program study, and Fire Safety engineering group Universitas Indonesia.

6. References
[1] Tumpahan Minyak Risiko Tinggi di Laut Masih Terus Mengintai Kompas 2017
[2] Clark R B 1986 Marine Pollution United States: Oxford University Press New York
[3] The International Tanker Owners Pollution Federation Limited 2012 Use of Skimmers in Oil Pollution Respoane Impact PR & Design Limited, Canterbury, UK
[4] Widiaksana N 2017 Analisis efektivitas pengangkutan tumpahan minyak menggunakan oil skimmer tipe piringan pada skala laboratorium Universitas Indonesia