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**Research Article**

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# Oil Spill Recovery Enhancement Using a Modified Portable Weir Skimmer

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**Abstract** Increasing of oil spill due to accidental events, pipeline breakdown and uncontrolled oily wastewater are of the extremely dangerous, harmful to the environment and eventually affects human life. New technologies and/or modifying the exiting techniques are of great importance to be achieved to control the spilled oil. Many types of oil skimmers as mechanical devices used in cleanup oil spill are developed, designed and modified to improve their performance. Weir skimmer is one of these skimmers that is used as an oil skimming mechanical device by setting its edge on the interface of oil/water surface in the controlled area. High oil recovery rate (ORR) is one of the main advantages for weir skimmer but its oil recovery efficiency (ORE) is too low due to the higher water content in the collected volume of oil/water. In the present study, the weir skimmer is modified to improve its performance by constructing two identical weir skimmers on a portable boat as a floating equipment in addition to two adjustable collecting arms attached to the boat sides. The suggested model is tested for different arms angle $60^o$, $90^o$, $120^o$, $150^o$ and $180^o$ at different boat speed ranging between 0.0-0.5 m/s to obtain the model performance. A better performance is reported and obtained based on boat speed and arms angle to be recommended.

**Keywords** Oil spill, oil skimmer, weir skimmer, oil recovery rate, oil recovery efficiency

## 1. Introduction

Oil spill is one of the uncontrolled problems due to increase of oil exploration, oil transportation, oil industries and oil services. Cleanup the spilled area without using chemicals or burning is one of the greatest importances to protect human life. Mechanical oil spill devices – oil skimmers – are more safe and better to environment. Mechanical oil skimmers can be classified into two types oleophilic and non-oleophilic. The oleophilic type consists of adhesion surface in contact to oil and water and scraping or squeezing mechanism to separate oil or oil and water from the contact surface. Such types as disc skimmers, drum skimmers, belt skimmers and mop skimmers. Their oil ORR and ORE are different based on many factors related to design, material used, oil properties and sea conditions (waves and currents). Some of researches dialing with the design itself others for developing the exiting design or skimmer material to improve their performance. Christodoulou et al. [1-2] investigated disc skimmer performance experimentally. El-Minshawy [3] modified the traditional disc skimmer using corrugated surface. Turner et al [4-6] test a new disc skimmer of-T-shape. Hammoud and Khalil [7-8] determined the effect of different disc material. El-Zahaby et al [9] studied the effect offset angle for a disc skimmer. Drum skimmer was covered by Hammod and Khalil [10]. Broje and Keller [11-13] improve the dum skimmer performance in two stages, the first was by changing drum material while the second by changing the drum surface shape to be V- patterned. Belt skimmer was tested by Shoier [14] and Hammoud and Khalil [15]. Afify [16] studied the flow over the belt surface as well as the flow patterns of oil over the water surface. Kassab et al. [17-18] examined the operating and environmental parameters on the performance of belt Skimmer at different operating coditions. Kassab [19] predicted belt skimmer performance as function of operating and environment parameters. Patel [20] compared various belt skimmer designs concluding their efficiency. The non-oleophilic skimmers depend on a suction mechanism such as weir skimmers and vacuum skimmers. Weir skimmer is most efficient recovery device that can reduce the time and cost of the cleanup and prevent significant environmental damage. Weir type skimmers have large vacuum hoses and efficient vacuum pump to suck in oil resulting in high ORR. McCracken et al. [22-23] started their experimental study mechanism of adjusting weir simmer setting. Jensen et al. [24and25] improved the floating of weir skimmer by gravity forces as a driving force to move oil towards the weir. Topham [26] developed a model for weir skimmer. HUDSON industries [27] engineered a slotted pipe weir skimmer across wastewater tank. Hammoud [28] enhanced oil spill recovery for weir skimmer by using multi-water jet vortex flow.

From the previous literature it is found that weir skimmers have the highest ORR for all types, this lead to think seriously about selecting it and invent an innovative way to increase its performance. The objective of this study is to modify the weir skimmer design to improve the existing mechanical performance so that it can be used efficiently under different operating conditions. The modified weir skimmer suggested in the present paper consisted of two weir skimmers constructed on moving boat sides. The two skimmers attached by two arms. One arm on each side of the boat to help in collecting oil during the boat movement. The angle between the attached arms can be adjusted using pneumatic actuators. The system was examined experimentally on two stages: In the first stage a laboratory scale model is to be tested at certain arms angle for different boat speed ranging 0.0 - 0.5 m/s. In the second stage the model is tested at different arm angles at 60$^o$, 90$^o$, 120$^o$, 150$^o$ and 180$^o$ to obtain the model performance at the same boat speed range examined in the first stage of experiments.

## 2. Experimental Test Set up

2-D drawing for the suggested modified weir system shown in Fig.1. The system consists of two identical weir skimmers (3) constructed on both sides of a moving boat (1). Two pneumatic arms (2) are fitted with weir skimmers one on each side. The arms angle $(\theta)$ can be adjusted at the desired angle using two pneumatic cylinders (4). Weir skimmers outlets are connected to suction pump which directs its sucked flow of water and oil into a collecting tank (5) fixed on the boat. The boat speed, suction pump and arms angle can operate separately using remote control system. 3-D drawing in Fig.2 for the proposed system -Portable Weir Skimmer– includes components used in the test: boat, arms, pneumatic cylinders controlling arms and oil collecting tank**.** Fig. 3 shows the actual testing for angle change facilities in the lab pool testing rig.

## 3. Test Procedure

Two pneumatic cylinders attached to arms on both boat sides are used to examine the efficiency and facilities of the proposed system by changing the angle between the two adjustable arms. The two arms here help in collecting a higher oil amount directed to the weir skimmers on both sides of the boat as shown in Fig.1. The arm angle has the facility to adjusted using a remote controlled switch or a mobile. After the angle is selected, the boat floatation is adjusted to set the weir skimmers edges in the oil/water interface, then the boat is ready to move with the desired speed to skim oil from the oil spilled area. Suction pump is switched on while its suction connected to the weir skimmers on both boat sides. The pump discharge mixture of oil and water can be collected in the tank over the boat. The system has the facility to change the arms angle, boat speed and boat direction on the sit. So higher oil recovery rate maximized with proper oil recovery efficiency. Tests were performed into two stages:

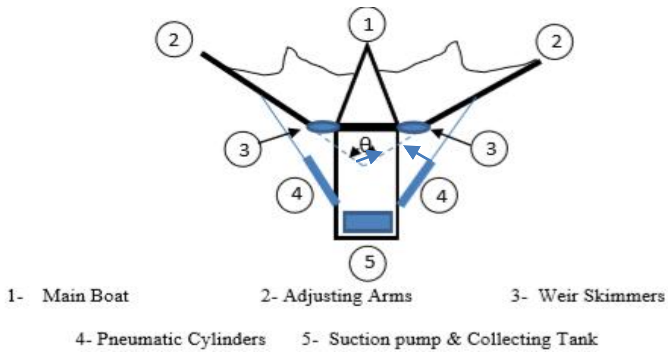


*Figure 1: Test Rig Components*

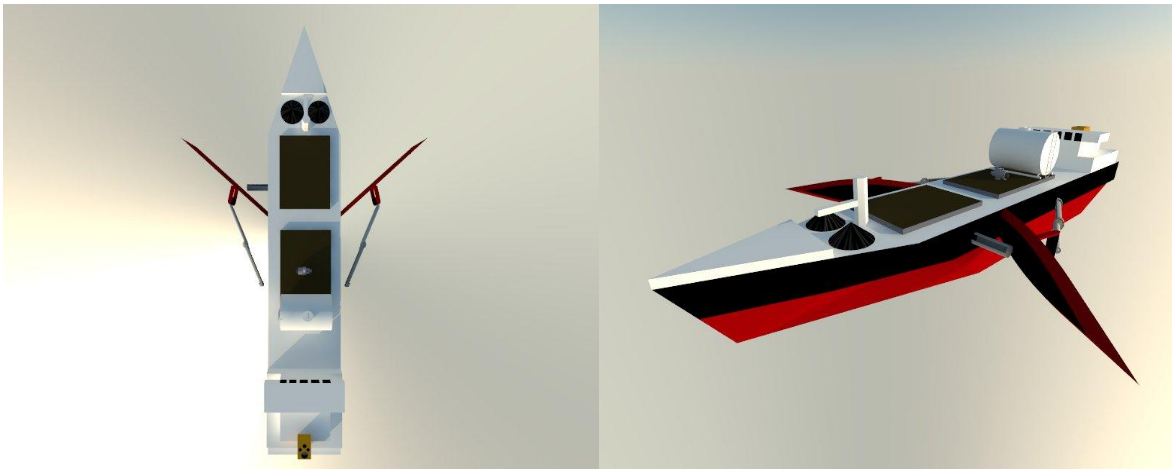

*Figure 2: Proposed System: Portable Weir Skimmer*

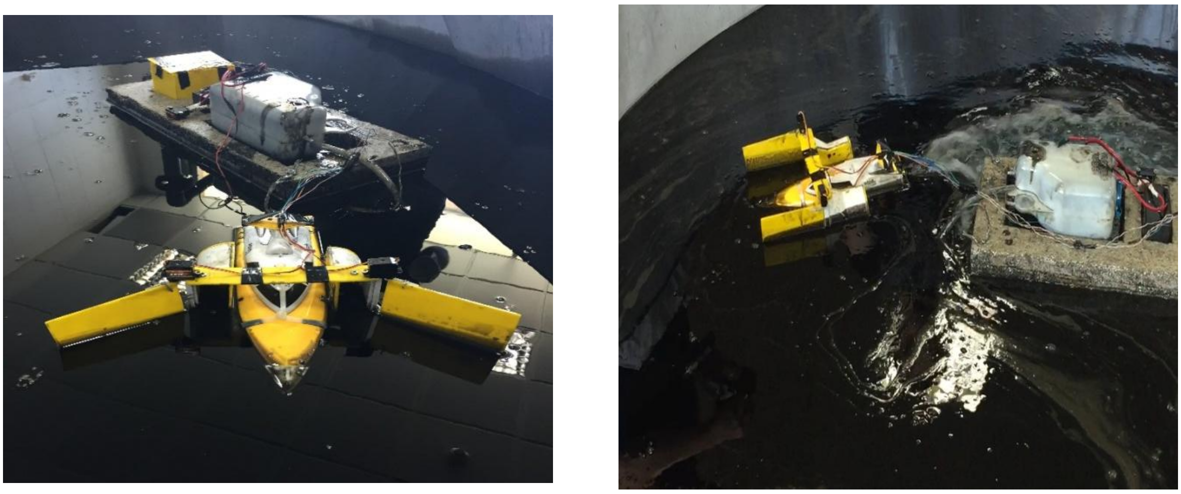

*Figure 3: Actual testing for arms angle change facilities*

The first stage was examined byselecting the arms angle $(\theta)$ value: 60°, 90°, 120°, 150° and 180°. At certain selected angle within the tested values, boat speed was selected, controlled and ready for starting the test. At the same time the suction pump was turned on. The oil and water collected in the tank in a period of time was transferred to a measuring and calibrated tank. The volume of oil and volume of water were measured after 24 hours to avoid oil emulsion and obtaining two separate volumes for the skimmed mixture of oil and water. The oil recovery rate (ORR) was calculated from the equation:

$$ORR = \frac{skimmed\ oil\ volume}{Time} = \frac{V_o}{T} cm^3/s$$

And the oil recovery efficiency (ORE) was deduced from the equation:

$$ORR = \frac{skimmed\ oil\ volume}{Total\ skimmed\ volume\ of\ water\ and\ oil} x\ 100$$

The second stage for system examination was to test the system for the same angle at different boat speeds ranging from 0.0 to 0.5 m/s then continue the procedure as the first stage.

**4. Results and Discussion**

Fig.4 shows the oil recovery rate (ORR) vs. the boat speed for different arms angle $(\theta)$. It was found that ORR had a direct proportional relation with the boat speed for all of tested angles. This was due to increase in oil collected volume at higher speeds during less time. More details for the effect of $(\theta)$ at different boat speeds is presented in Fig. 6. From the figure results it can be concluded that at certain boat speed the arms angle $(\theta)$ of 90$^o$ had the highest (ORR), while the (ORR) increased as the angle increased in the range between 60$^o$ and 90$^o$ due to higher collecting oil amount with higher oil thickness related to smaller area corresponding to smaller angles. But in the range from $(\theta)$ 90$^o$ to 180$^o$increasing angle over 90$^o$ led to lower (ORR) due to corresponding larger area related to arms angle lager than 90$^o$.Fig.5displays the oil recovery efficiency (ORE)vs. the boat speed for different $(\theta)$. It can be noted that increasing the boat speed increased the (ORE) to its maximum value corresponding the boat speed nearby 0.3m/s. After that value of boat speed, the (ORE) decreased due to high amount of water collected in the mixture of water and oil over the weir edge. That trend of results was obtained for all selected and tested values of $(\theta)$. For farther information about the effect the $(\theta)$ on the (ORE) Fig. 7 was constructed and same trend was obtained for the relation of ORR against (θ). The arms angle $(\theta)$ of 90$^o$ had the highest ORE. ORE increased as $(\theta)$ increased between $(\theta)$ 60$^o$ and 90$^o$ due to small controlled area resulted from smaller angles. While that trend changed for higher values of $(\theta)$ after 90$^o$ up to 180$^o$ due to lower oil amount collected in the mixture of water and oil for larger angles and lower oil thickness.

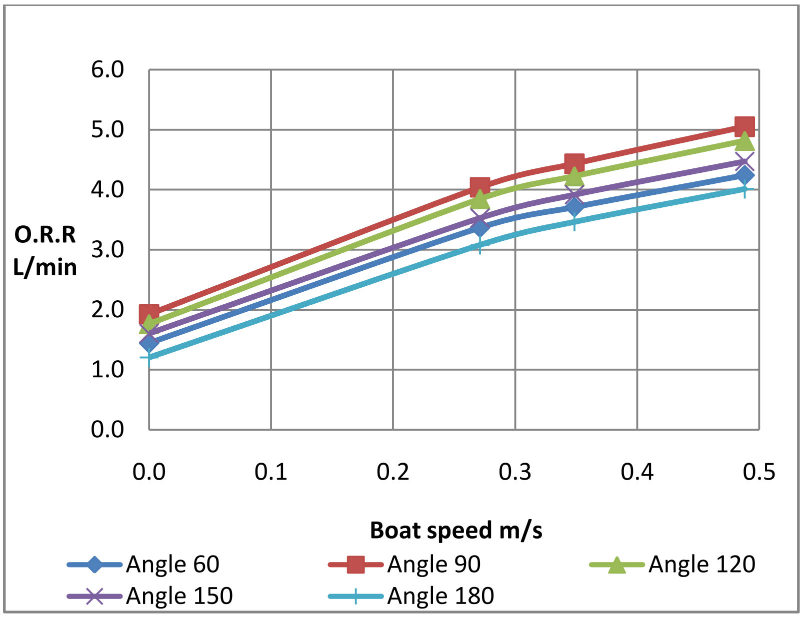


*Figure 4: ORR at Different Arms Angle $(\theta)$ for Different Boat Speeds*

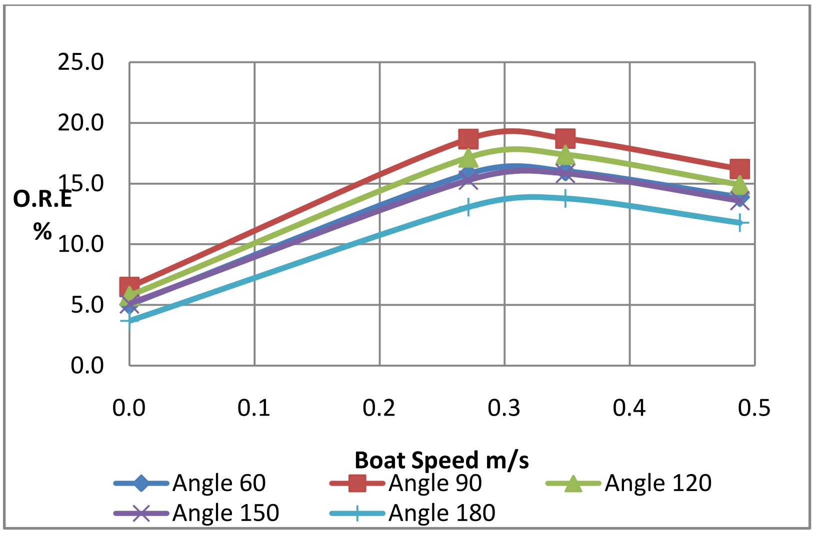


*Figure 5: ORE at Different Boat Speeds for Different Arms Angle $(\theta)$*

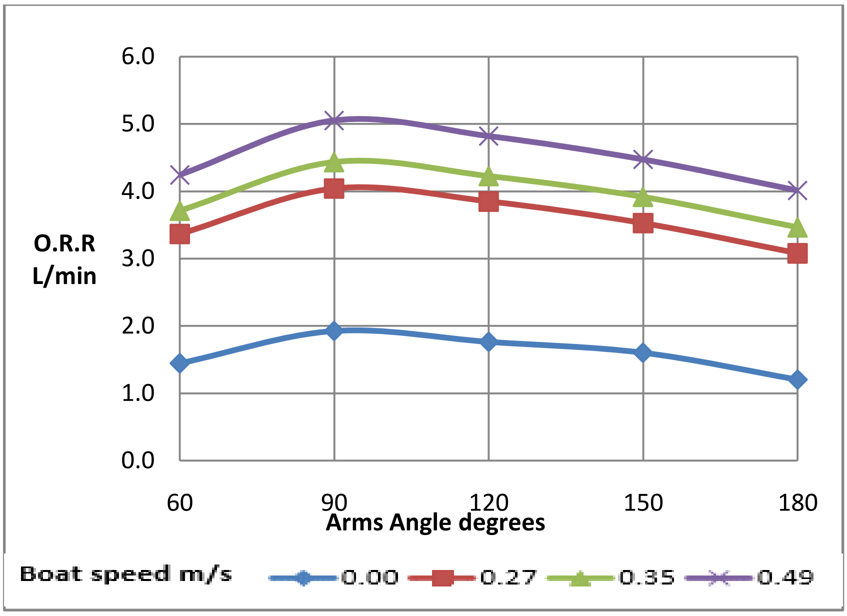


*Figure 6: ORR at Different Arms Angle $(\theta)$ for Different Boat Speeds*

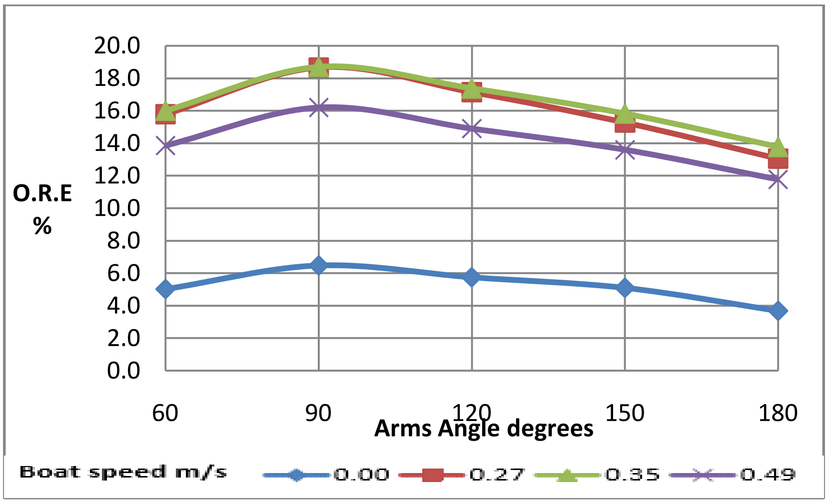


*Figure 7: ORE at Different Arms Angle $(\theta)$ for Different Boat Speeds*

## 5. Conclusions

1. As the boat speed increases, the proposed system oil recovery rate increases.
2. The system oil recovery efficiency increases for boat speed reached to its maximum value at a speed nearby 0.3m/s for all arms angle, then decreases for higher boat speed.
3. At certain boat speed:
   - The oil recovery rate and oil recovery efficiency increase as arms angle between $60^o$ and $90^o$
   - The maximum values for oil recovery rate and oil recovery efficiency were obtained for arms angle of $90^o$.
   - The oil recovery rate and oil recovery efficiency decreased after the maximum values obtained at $90^o$for angles between $90^o$ and $180^o$.

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