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Hollow Wing Technique to Enhancing Conveyor Performance on Marine Debris Collection

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Abstract: Conveyor-based marine debris collection has to be enhanced. Due to their wide form, ability to flow water, and minimal weight, hollow-winged conveyors can be an alternative. This investigation was carried out to find out how effective the hollow wing approach is at collecting marine debris in the ship's conveyor. This involves a catamaran type with a hollow-winged static conveyor. The hollow wing model is used in four different ways. The circle hollow wing model 18.75 cm 60 deg has a higher marine debris collecting ratio than other models, according to the results.

Keywords: collection; hollow wing; marine debris; static conveyor; wide shape.

1. Introduction

Marine debris is a problem for all countries that must be resolved immediately[1)] . Because when it is in the sea the marine debris will be drifted to everywhere. 80% of marine waste comes from land waste, most of this waste is plastic waste[2,3)] . Various countries are trying to find the best solution to solve this problem through scientific meetings, scientific studies[4–6)], and also by formulating various policies[7–9)]. The marine debris is located in various places such as ecosystem areas[10)], coasts, populated islands[11)], rivers[12)] , and deep seas[13)]. It is estimated that around 19 to 23 million metric tons, or 11%, of plastic waste that was generated globally in 2016 entered marine areas, including marine ecosystems [14)]. Other data stated that every year around 8 million metric tons of plastic waste ended up in the oceans and lowered the Marine Health Index[15–17)]. Furthermore, 192 coastal countries dumped 275 million tons of debris into the sea[18)], and 86% of this debris comes from various rivers in Asia before entering the sea[19)]. This has prompted governments and international organizations to make serious commitments to reduce marine debris in many countries. Many countries have developed regional and national waste management plans. The plan starts from the mainland and involves the community in a more active role. This also includes the development of technologies for cleaning and treating marine debris [20)].

This is based on a study of existing research on marine debris prevention and collection technology by previous researchers[21)]. The findings indicated that there are 52 technologies that can either avoid or gather plastic pollution. Of them, 59% were devoted only to removing garbage made of macroplastic from rivers. Then, few technologies—and those that did—tried to stop the leaking of plastic pollution, and those that did so had a narrow reach. Reviews of technologies to stop or lessen marine plastic waste have also been done in developing nations[22)]. It made use of a platform created by Ubuntu dubbed "GreenHouse." The majority of currently accessible technologies for collection were as a result.

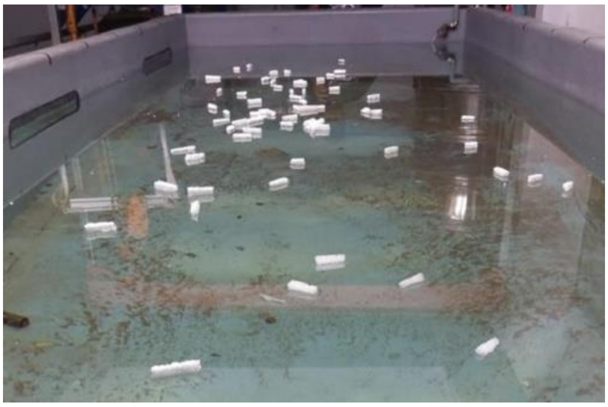
Boyan Slat, CEO of the Ocean Cleanup Foundation, proposed the concept of cleaning up marine debris "why move through the ocean if the ocean can move through you?"[23)]. Likewise, research on passive ocean plastic collector under rough sea conditions also discusses marine debris collection in relation to ocean speed, currents, wave height, wavelength, plastic weight, and collection rate [24)]. However, this notion can only be employed in areas with strong currents and waves; lakes, sedentary rivers, and other peaceful waterways cannot be used because they lack of big currents and waves. Accordingly, neither the impacts of changing wing dimensions nor the effects of ships or conveyors are relevant to this investigation. Conveyors are the most often utilized instrument for gathering marine trash, according to assessments of marine waste cleaning technology conducted by other researchers[25)]. Research on the effect of hulls number using a conveyor on ship resistance force was carried out by Sugianto et al[26)]. Numerical research that was also conducted by Sugianto and Chen[27)] showed that hollow wings have a lower resistance force than solid wings.

However, experiment study using conveyors to collect marine debris is rarely found. Additionally, there is no research on the efficiency of hollow wing conveyors in removing marine trash. Conveyor-based methods for collecting marine debris need to be improved because they are not very successful at doing so. Due to their wide form, ability to flow water, and minimal weight, hollow-winged conveyors can be an alternative. In this study, an experiment was carried out to determine the impact of a catamaran ship's circular hollow wings, oval hollow wings, and no-wing conveyors on the efficiency of marine trash collecting. When comparing the amount of Artificial Marine Debris (AMD) collected to the total AMD before the model enters the sail zone, the ratio of AMD caught is utilized as a measure of effectiveness. The hollow wing model is utilized in four different configurations: circle hollow wing 12.5 cm 30 deg, circle hollow 18.75 cm 60 deg, oval hollow wing 12.5 cm 30 deg. Six times, with varying speed variations, the experiment was run in a static tank. Then, analysis of the reasons why the hollow wing conveyor wasn't catching marine debris as well as an further research proposal to advance this study were made.

2. Experimental Program

2.1 Experimental Apparatus

Experimental research was conducted in a static tank with length, width, height of 5.8 m, 1.8 m, 1m (Fig. 1a) and the water depth of 0.7 m. The pure water condition is calm water. At the beginning of the experiment, there were no waves at all due to wind and current. In the next experiment, small waves were formed on the water surface in a static tank as a result of model movement from the previous experiment. The research location was conducted at the Department of Systems and Naval Mechatronic Engineering, National Cheng Kung University. To replace the original marine debris, Artificial Marine Debris (AMD) is used which has been spread over the water surface in static tanks. AMD made with 1:8 scale from the original size. So the size of this experiment is smaller than the original marine debris



(a)

(b)

Fig. 1: Artificial marine debris: (a) AMD on water surface (b) pieces of AMD

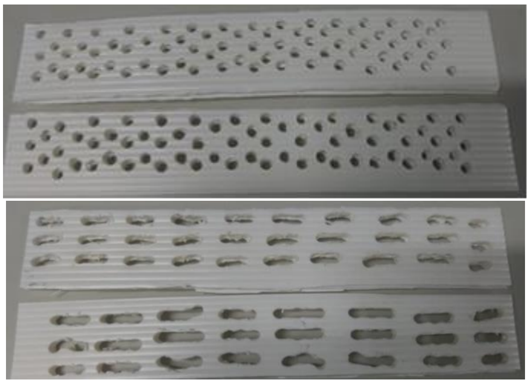
AMD is made of styrofoem with considering, firstly, it is light in shape and can float on water with the size of marine debris that has been designed, secondly, it is easy to make and cheaper than wood[28]. The AMD was measured to be about 3-5 cm long and 1-1.5 cm wide (Fig. 1b). The number of AMD used is 80 AMD.

2.2 Model configurations

There are five models used in this experiment. They are catamaran without conveyor, catamaran with conveyor using circle hollow wing 12.5 cm 30 deg, catamaran with conveyor using circle hollow wing 18.75 cm 60 deg, catamaran with conveyor using oval hollow wing 12.5 cm 30 deg, and catamaran with conveyor using oval hollow wing 18.75 cm 60 deg (Fig. 2). The shape of catamaran hull used is an inner flat hull with a static conveyor between the two hulls. The hollow shape is not too smooth because it made by using electric soldering iron. The same ratio used in all hollow wing model to make a fair comparison, the ratio of the area of open (hollow) and closed areas. So even though the shape of the hole is different. But the hollow area ratio is the same. The data details are given in Table 1.

The conveyor and wing are constructed at 1:8 scale. The ship model used is a catamaran type, because based on previous numerical research it shows that catamarans are better at collecting marine debris[26,29]. The catamaran ship model is made of wood, because, first, it keeps the ship afloat according to the draft designed, second, it is easier to build and cheaper than other materials. Next, the conveyor used is considered static and does not move. Furthermore, styrofoam material is used for conveyors because the shape of the conveyor is static, so any material can. However, styrofoam was chosen because it is easier to install and shape according to the design. Afterwards, the solid wings use plastic because the wings used are hollow, so this material is the easiest to make holes in the wing.

(a)



(b)

Fig. 2: Model (a) top view (b) circle hollow wing (up) and oval hollow wing (down)

Table 1: Principal particulars of model

Parameter	Model
Length between perpendicular (cm)	50
Breath (cm)	37
Draft (cm)	2.5
Separation ratio S/L	18/50
Conveyor wide (cm)	18
Conveyor length (cm)	10
Conveyor thickness (cm)	1.5
Wing length (cm)	12.5, 18.5
Wing height (cm)	3
Wing thickness (cm)	0.4

2.3 Experiment procedures

The procedures are carried out on the five models. As shown in experimental setup on Fig. 3, the catamaran model and the wing conveyor were pulled manually using a thread fixed in the center of the model. In addition, two other threads were also attached to both sides of the model to make the screen path of the model a straight forward one. This research was conducted in calm water conditions before the model was pulled. The force used to pull the model is not same in every model, thus it created a different speed on each model. The limitation is the same distance and different times chosen in moving the model. Models were pulled with six speed variations ranging from small speeds to high speeds. This velocity value was obtained by dividing the time during which the model moves with the path length. AMD collected only those that are on the water surface. Since the conveyor is static, the marine debris that gathers around the conveyor is considered the collected marine debris. The depth of AMD that can be collected is as deep as the wing conveyor that immerse into the water, which is about 0.5 till 1 of the ship's wing height conveyor.

Fig. 3 Experiment setup

3. Result and Discussion

The next parts thoroughly entail the recorded (observed and measured) results for collected AMD ratio curve, AMD lost ratio, AMD in sail zone, AMD collected per sail zone area, and AMD collected per all AMD in the static tank. In addition, an analysis has been conducted on the cause of AMD not caught by the catamaran ship with hollow wing conveyor model.

3.1 AMD collected and AMD in sail zone

The information gathered included the AMD acquired at each speed as well as the AMD in the sail zone. The region where the model moves is known as the sail zone. The water surface area swept by the wing conveyor is located here. Figure 4 shows the sail zone as the yellow area. When the model has not been moved to collect AMD, it is in the sail zone. The water surface in the static tank is shown in its initial state in Figure 4. At that time, the catamaran model with conveyor employing an oval hollow wing measuring 12.5 cm and 30 degrees had not been drawn. The six distinct numbers in Figure 4 illustrate how many AMDs there are in the sail zone at each model speed. The other four models, a catamaran without a conveyor, a circle hollow wing measuring 12.5 cm by 30 degrees, a catamaran with a conveyor using a circle hollow wing measuring 18.75 by 60 degrees, and a catamaran with a conveyor using an oval hollow wing measuring 18.75 by 60 degrees.

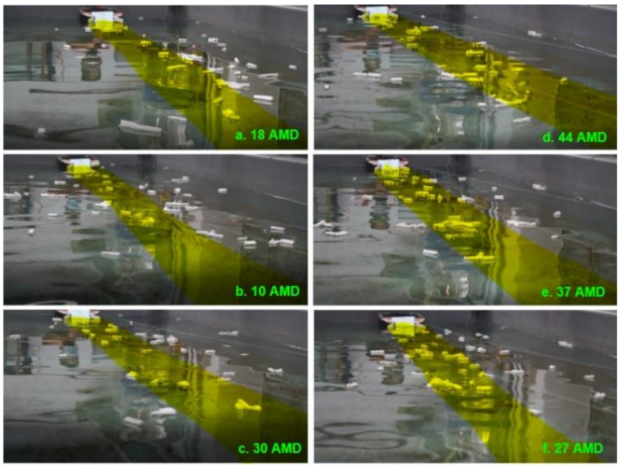


Fig. 4 AMD in sail zone of oval hollow wing 12.50 cm 30 deg

The wing conveyor collects AMD as it runs ahead. Figure 5 shows the AMD that a catamaran model with conveyor and an oval hollow wing at a 30 degree angle at six different speeds was able to capture. The identical procedure is followed in the remaining four models, but for each model and each speed, a different number of AMDs are captured. From one experiment to the next, and so forth, the model's pulling speed is not linear but rather random. As a result, AMD's captured as shown in Figures 5a to 5f are similarly random.

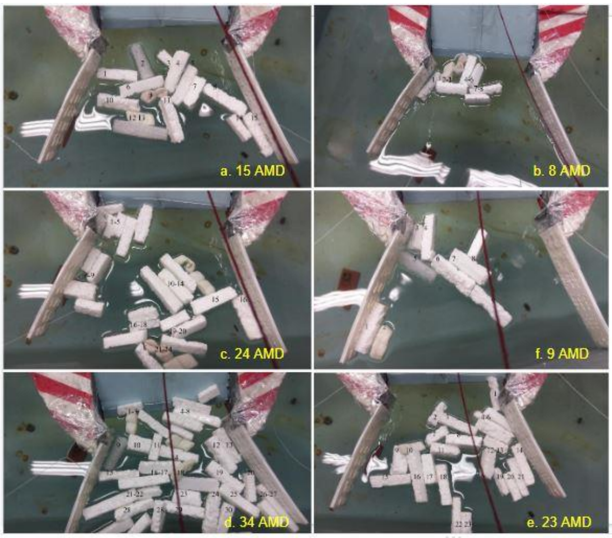


Fig. 5 AMD collected of circle hollow wing 12.50 cm 30 deg

Fig. 6 displays a comparison graph of the total number of AMD gathered from the five models. The circle hollow wing type with an 18.75 cm length and a 60 degree angle can gather the most AMD at practically all speeds with the exception of the second speed, which is 0.146 m/s, according to the comparison on the graph. This occurs because the amount of AMD collected is likewise modest at this speed due to the low number of AMD in the sail zone (Fig. 7). The graphic pattern of the total number of AMDs collected (Fig. 6) and AMD in the sail zone (Fig. 7) then had nearly the same line pattern when compared.

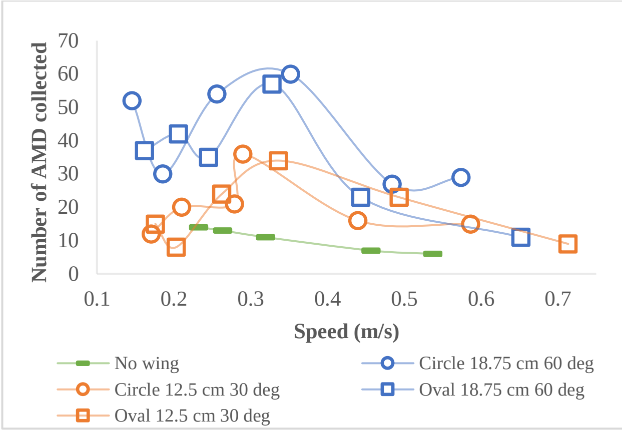


Fig. 6 Number of AMD Collected

Fig. 8 shows a comparison of AMD's data-gathering capability across the five models. The difference between the AMD in the sail zone region and the collected AMD is known as the collected AMD ratio. The most accurate comparison to use when evaluating how well the models collect AMD is this one. Since there may be disparities in the number of early AMD before the model moves or AMD in the sail zone (Fig. 7), the comparison will not be fair if it merely compares the number of AMDs collected from the five models (Figure 6).

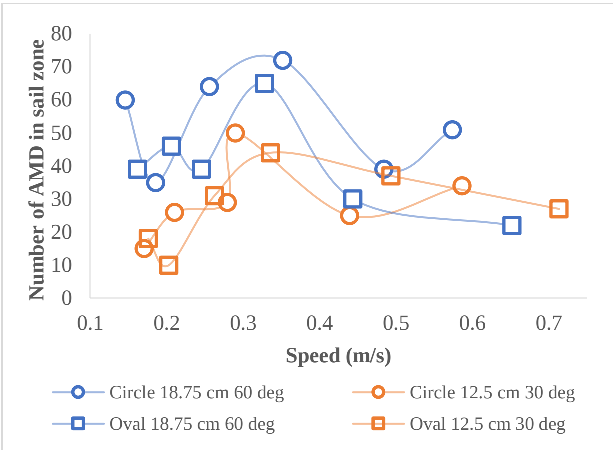


Fig. 7 Number of AMD in sail zone

Additionally, it is inappropriate to evaluate the efficacy of those models using the total AMD values obtained from static tank comparison. Because there are the same amounts of AMD overall in static tanks in all circumstances. Therefore, doing this comparison will result in a graph that is identical to the AMD collection graph. It can be observed by contrasting Figs. 6 and 9. The two figures can be compared to see that the patterns in the two photographs are the same. Additionally, it was unfair to compare the AMD gathered per sail zone area (AMD/m2) in order to determine how effective these models are (Figure 10). Due to the fact that each model's sail zone area is unique. The sail zone area will be wider the longer the wing conveyor, the wider the sail zone area will also be the larger the angle of the wing conveyor, and vice versa. Therefore, comparing the amount of AMD collected to the amount of AMD before it was collected, which was exclusively in the sail zone, is the most accurate approach to determine how effective the instrument is.

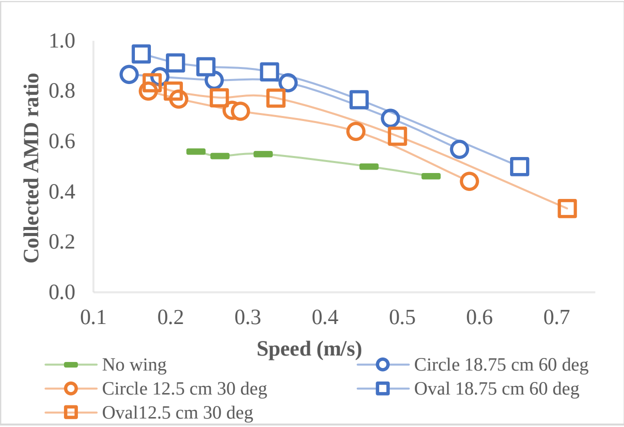


Fig. 8 Collected AMD ratio

It can be seen from the comparison in Fig. 8 that the collected AMD ratio will be smaller, indicating that less waste is collected, the faster the model travels to collect trash. Therefore, it can be inferred from this graph that a low speed is ideal for collecting AMD. The AMD collected ratios for the five models may then be compared to identify which one is the most successful at gathering AMD. Therefore, it is also known sequentially that the conveyor using the oval hollow wing of 18.75 cm length and 60 deg angle, circle hollow wing of 18.75 cm length and 60 deg angle, oval hollow wing of 12.5 cm length and 30 deg angle, and conveyor without the wing, has the AMD collected ratio from highest to lowest. Additionally, the length of the wing conveyor has a greater impact on the collection of marine debris than the hollow shape of the wing conveyor. However, as information comes from the AMD collection, more study is required to determine the drag force produced by this model variant.

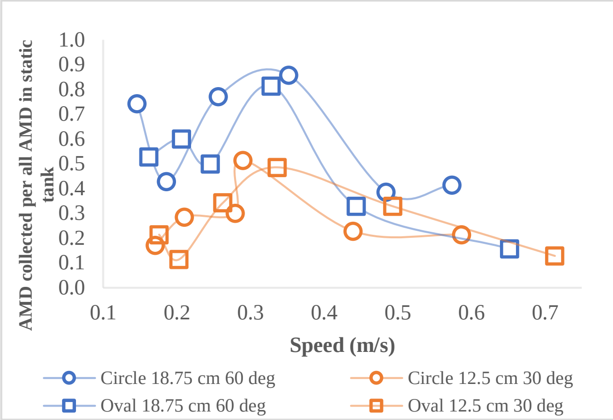


Fig. 9 AMD collected per all AMD in static tank

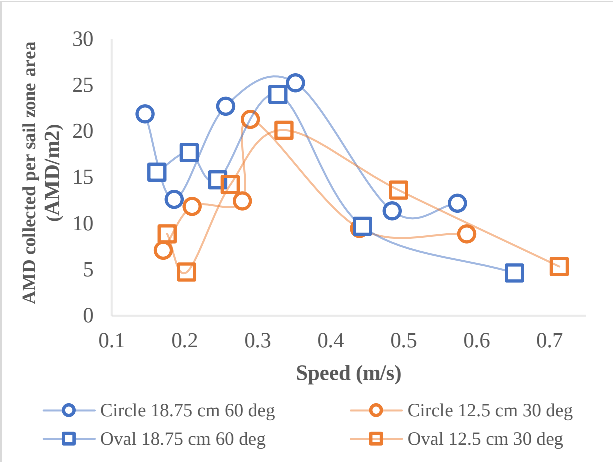


Fig. 10 AMD collected per sail zone area

3.2 AMD collected and AMD in sail zone

The AMD in the sail zone that is missed by the wing conveyor is referred to as lost AMD. The number of AMD in the sail zone minus the number of AMD caught equals therefore the amount of AMD lost. The AMD loss of the five models at six different speeds is shown in Fig. 11. Due to the fact that each speed is different, it is impossible to determine from the figure which model AMD lost the most. The catamaran with the conveyor using the oval hollow wing 18.75 cm 60 degrees has the most AMD lost when traveling at low speeds, but at medium speeds, the catamaran with the conveyor using the circle hollow wing 12.5 degrees and the oval hollow wing 12.5 degrees have the most AMD lost.

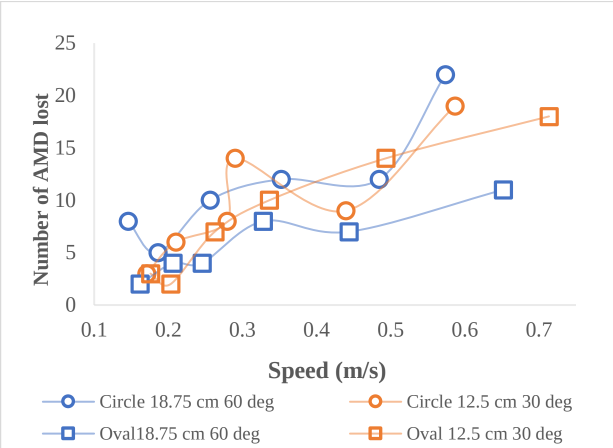


Fig. 11 Number of AMD lost

The AMD lost ratio can be used to determine which model has seen the greatest AMD loss. The AMD lost ratio measures how many AMDs were lost compared to how many were in the sail zone. According to Fig. 12, the catamaran with a conveyor using a circle hollow wing of 12.5 cm 30 degrees, the catamaran with a conveyor using an oval hollow wing of 12.5 cm 30 degrees, the catamaran with a conveyor using a circle hollow wing of 18.75 cm 60 degrees, and the catamaran with a conveyor using an oval hollow wing of 18.75 cm 60 degrees have the highest to lowest AMD lost ratio, respectively. The catamaran with conveyor employing oval hollow wing 18.75 cm 60 deg is the model that is best at collecting AMD since it has the lowest AMD lost ratio, according to the comparison of the three models.

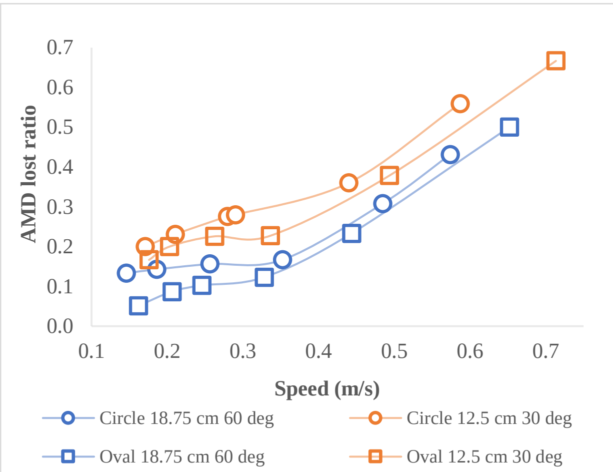
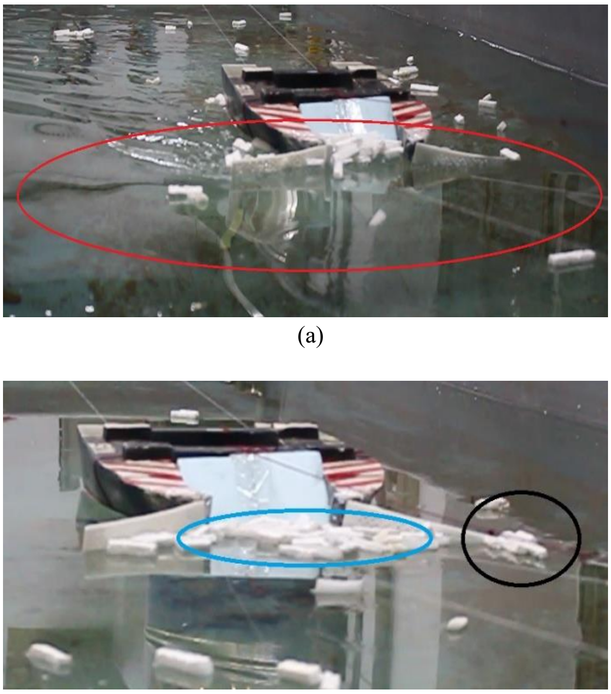


Fig. 12 AMD lost ratio

3.3 Cause of AMD not caught by wing conveyor

Table 1 displays the movement pattern of AMD after the four models have been removed. Each model's low speed and high speed are used to collect the data. There are numerous reasons why AMD might not be picked up by the wing conveyor. The AMD is initially edging away from the conveyor wing in a sideways motion. This only occurs with AMD near the end of the conveyor wing on low-speed machines. Waves produced by the model movement are causing AMD to shift sideways. Only the AMD at the end of the conveyor wing moves sideways from the conveyor wing because to the little waves that are created (Fig. 13b). There are several AMDs that go sideways and steer clear of the wing conveyor while the model is moving at high speed because the waves it creates are so huge (Figure 13a). AMD in the front of the conveyor wing likewise moves away, in addition to AMD at the conveyor wing's end. Thus, the AMD that was collected only amounted to a small amount. This is the reason why gathering AMD is best done at modest speeds (Fig. 8).



(a)

(b)

Fig. 13 AMD collected in some conditions: (a) wave generated by ship motion (b) AMD move to side (black), AMD collected (blue), and space in front of wing conveyor is still available

The AMD passed through the wing, which is the second reason the wing conveyor did not catch it. The waves generated by the movement model were huge and passed over the wing conveyor because this typically happens at very high speeds. However, in the present tests, the hollow wing conveyor, this is not the case (Table 2). The reason for this is that the wing conveyor contains numerous holes, allowing water to pass through them and preventing large waves from resulting from the water colliding with the wing conveyor. The final reason the AMD escaped detection was that there was no more room in front of the conveyor. The AMD captured is not transported aboard the ship since the conveyor model employed is a static conveyor model. The AMD was gathered in front of the conveyor, which is what it signifies. The AMD can no longer be captured when the area in front of the conveyor is full. On all four models, however, the area in front of the conveyor wing is still free at all speeds (Table 2). Therefore, this can't be the cause of the AMD being missed.

Table 2. AMD movement pattern

Pattern	Model							
	Circle hollow wing 12.5 cm 30 deg		Oval hollow wing 12.5 cm 30 deg		Circle hollow wing 18.75 cm 60 deg		Oval hollow wing 18.75 cm 60 deg	
	Low speed	High speed	Low speed	High speed	Low speed	High speed	Low speed	High speed
AMD collected	✓	✓	✓	✓	✓	✓	✓	✓
Wave generated by ship motion	small	high	small	high	small	high	small	high
AMD move to side	some	many	some	many	some	many	little	many
AMD pass through the wing	no	no	no	no	no	no	no	no
Space in front of ship	yes	yes	yes	yes	yes	yes	yes	yes

4. Conclusion

The issue of marine debris is still open for discussion. To find out how effective the hollow wing approach is at collecting marine debris, it is proposed and experimentally tested on a ship's wing conveyor. The outcomes of the four models that were employed in this study were then compared to a model without a wing conveyor. The circle hollow wing model 18.75 cm 60 deg has a higher marine debris collecting ratio than other models, according to the results. 2) The faster the model moves to collect AMD, the lower the collected AMD ratio will be, which indicates that less waste is collected. This model can also be 40% more successful at collecting marine debris than the one without wings. This occurs because there is a correlation between the model's speed and the magnitude of the waves it produces. As a result, AMD shifted to the side. The model with the highest AMD lost ratio is a catamaran with a conveyor using a circle hollow wing of 12.5 cm and 30 degrees. 3) Based on comparison in the lost ratio graph, it is known that this is the case. 4) The longer the wing conveyor, as well as the larger the conveyor angle, the more AMD is collected, and vice versa. In order to gather marine debris, the length of the wing conveyor has a greater impact than its hollow design. But since this is coming from the AMD collecting side, further research is needed to determine how much impact this model difference will cause. Whether it is accomplished through numerical simulation or experimental testing in a towing tank. To create a tool that is sturdy, consumes little fuel, and performs effectively, it is also necessary to look more closely at the strength of the wing and conveyor structure. Future studies will also examine the technique for gathering marine debris using a conveyor wing placed at a specific water depth..

Acknowledgements

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