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Hull Number Effect in Ship Using Conveyor on Ocean Waste collection

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Abstract

The increase in ocean waste continues to grow from year to year, especially plastic and solid waste. Various ocean waste collection ships using conveyors exist, both in the form of designs and already in operation, but there has been no research on how many hulls are suitable for ocean waste collectors. This study aims to choose between the three-ship models, namely monohull type U, catamaran type inner flat hull, and trimaran type symmetrical. Assessment is based on ship resistance which relates to fuel consumption and flow distribution relates to ocean waste collection. This research uses Computational Fluid Dynamics (CFD) method which produces resistance, fluid flow velocity contours, and fluid flow patterns. Numerical simulation is based on Reynolds Averaged Navier Stokes (RANS). The turbulent model uses the standard k-epsilon equation. Then the volume of fluid sub-models used is open channel flow. The number of Eulerian phases is two. Moreover, the formulation of the volume fraction parameters used is an implicit body force. The results show that monohull type U is better than others in easiest to bring ocean waste closer to the conveyor and smallest resistance force. Then symmetric trimaran is faster than others in making ocean waste flow to the conveyor.

1. Introduction

The amount of ocean waste is increasing every year. Ocean waste is a solid and fluid object produced by humans directly or indirectly by being dumped or left in the sea. Ocean waste can be transported by ocean currents and wind from one place to another, and can even travel great distances from its source. Including ocean waste is marine debris, it ranges in size from micrometer to millimeter debris, medium-sized debris less than one meter long such as plastic bags, soda bottles and tens of meters long such as shipwrecks and lost cargo containers [1]. China and Indonesia are the largest contributors to marine plastic waste in the world, ranking first and second. Indonesia has a coastal population of 187.2 million who live within 50 km of the coast and annually generates 3.22 million tonnes of unmanaged waste and an estimated flow of 0.48-1.29 million metric tonnes of plastic waste per year into the ocean [2,3].

Based on data from Indonesia Central Statistics Agency, in 2017 the highest daily waste production was on the island of Java, especially Surabaya. The amount of waste in Surabaya is the second largest after Jakarta. However, Surabaya has the highest percentage of unmanaged waste in Indonesia, which is 37.1% [4]. The role of ships in ocean waste management can be done in the collection, sorting, and processing of ocean waste [5]. The use of digital technology to reduce ocean waste is also possible [6]. Ships generally use single hulls or monohulls, but over the last decade multi-hull ships have greatly evolved and it has become the dominant mode of marine transportation [7]. Thus, research on the use of multi-hull ships in ocean waste collection is very possible.

One of the multi-hull ships is a catamaran. This ship has a double hull connected by a bridge structure. Catamaran's advantage is that they provide lower resistance and have a large deck area that can be used to hold ocean waste [8]. There are three types of catamarans, namely inner flat hull, symmetrical flat hull, and outer flat hull. Inner flat hull which has the smallest resistance [9]. However, it is a catamaran without a conveyor waste collection device. Another multi-hull vessel is the trimaran. The ship has 3 hulls, namely one main hull and two side hulls [10]. There are three types of trimaran ships, namely symmetrical, deep asymmetrical, and outboard asymmetry. The symmetrical trimaran ship has a smaller resistance force compared to other ships [11]. However, it is a trimaran without a conveyor waste collection device.

In this research, selection of the appropriate number of hull ships for ocean waste collection is carried out, types of hull ship models used are monohull type U, catamaran type inner flat hull, and trimaran type symmetrical. The numerical simulation is based on Reynolds Averaged Navier Stokes (RANS) in CFD. This study provides information on the effect of using conveyor technology on the number of different ship hulls on the effects of marine debris collection is still scarce. As marine debris collection vessels using conveyors are emerging, both in design and in operation, but there is no research on how many hulls are suitable for marine debris collectors.

2. Methods

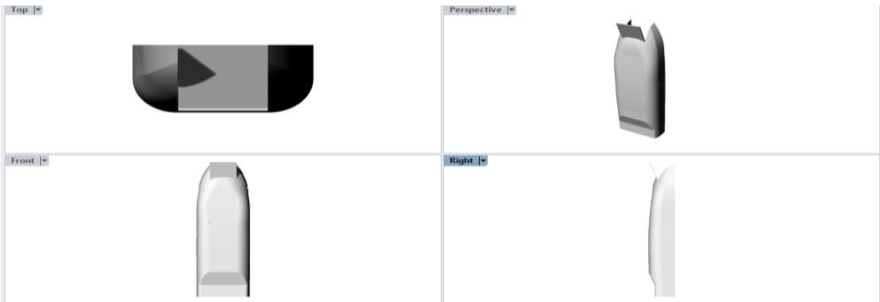
Ship main data used is ship data for collecting ocean waste for the Surabaya sea as shown in Table 1 [4]. The ship only serves to collect ocean waste and the capacity of the ship is 25 tons of marine debris. All three models have the same ship main data. However, for the catamaran, the distance between hulls is 2.4 m. While the hull distance of the trimaran is 0.587 m. The conveyor on this ship model is static, meaning that the conveyor does not move. The conveyor installed in the model has a length of 6.5 m, the angle between conveyor and water surface is 20 degrees, conveyor thickness is 0.1 m, and conveyor width is 2.4 m. The workings of an ocean waste collection ship equipped with a conveyor are to use a conveyor to collect ocean waste. Then ocean waste is collected into the space inside the ship [12]. Following the reference of several similar work vessels, the ideal speed of the ship and conveyor is 4 knots [13].

Table 1. Principal dimension of ship

Main Dimension	
Tipe	Collecting Waste Ship
LWL	16,448 m
Lpp	15,431 m
Bmld	4,8 m
Hmld	2,38 m
T	1,2 m
Cb	0,687
Vs	1,2,3,4 knots
Crew	4

2.1. Modelling

The three models used in this study are shown in Figure 1. Three variations of marine debris collection ship models, namely monohull type U, inner flat hull type catamaran, and symmetrical trimaran type. Models built using the computer-aided design (CAD) application.



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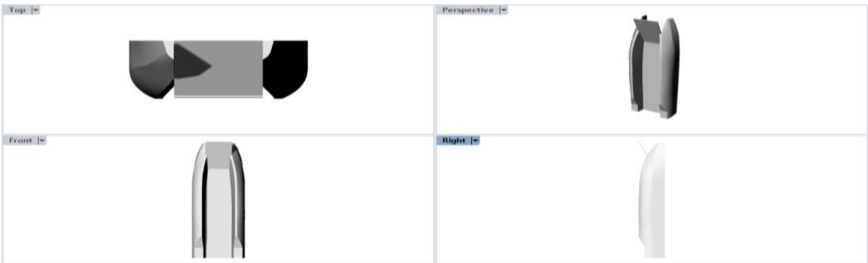

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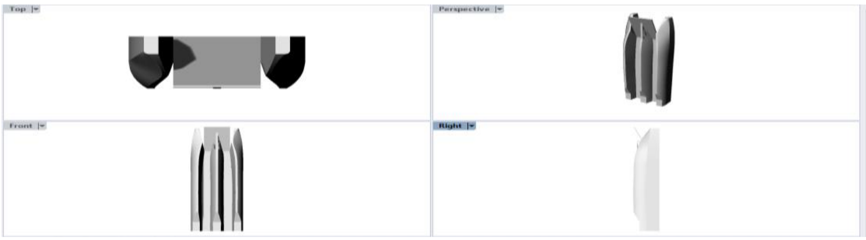

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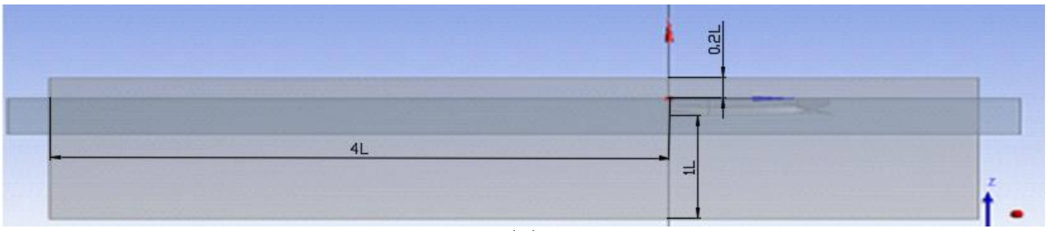
Figure 1. Variation of the ship and conveyor models: (a) U type monohull (b) inner flat hull type catamaran (c) symmetrical type trimaran.

2.2. Computational Domain

In the computational domain, the hull ship model with conveyor is modeled as a fluid domain. The domain boundary where the computational grid is modeled is from inlet to model is 2L, from model to an outlet is 4L, from model to sidewall is 0.4 L, and from model to top wall is 0.4 L (Figure 2). L is the Length Between Perpendiculars of the ship. So that at boundary conditions the pond has an inlet length to the model which is 30,862 m, model to outlet 61,724 m, model to sidewall is 8.5724 m, model to upstream is 3,0862 m, and model to downstream is 17,881 m.

The top, sides, and bottom of the domain are determined by slip boundary conditions. The hull is fixed to a no-slip wall. The inlet boundary is taken as inlet velocity. The outlet is located behind the hull model and it is set to outlet pressure. The inlet boundary condition is used to initialize the flow field in the domain. The symmetry condition is used because of the symmetry in geometry, which reduces the computational effort



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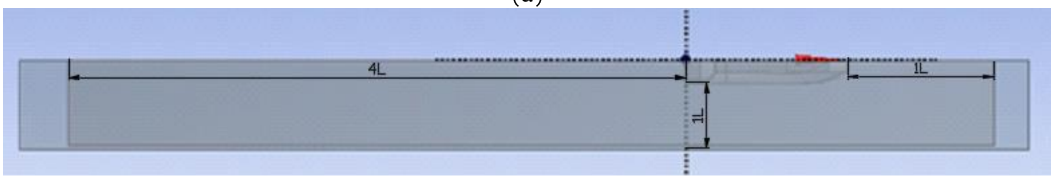

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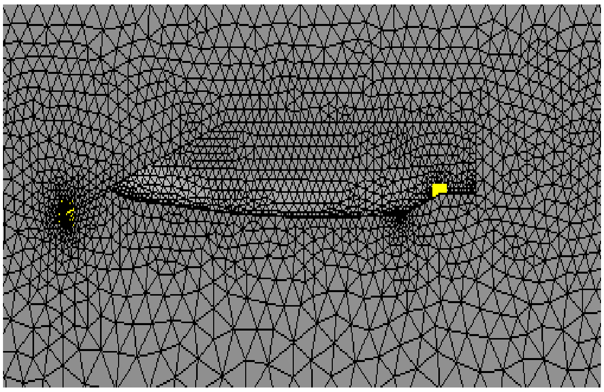
Figure 2. Geometry (a) Side view (b) Top view

2.3. Meshing

Meshing in CFD is the process of converting a continuous fluid domain into a discrete computational domain, so those fluid equations can be solved using numerical methods. The meshing grid of the ship and conveyor is as seen in Figure 3a. The type of mesh used is tetrahedral. A tetrahedron has 4 vertices, 6 edges, and is bounded by 4 triangular faces. This is used because this simulation uses a volume mesh.



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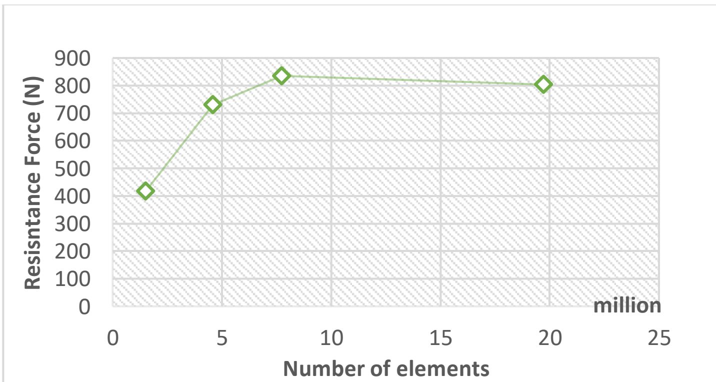

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Figure 3. Meshing: (a) Mesh in the computational domain, (b) Grid independent.

Mesh independence study was carried out on ship and conveyor models as shown in Figure 3b. This is to ensure convergence and accuracy of the meshing process. The variations in body sizing mesh and face sizing mesh used are 0.8 m and 0.6 m, 0.5 m and 0.3 m, 0.4 m and 0.3 m, and 0.3 and 0.1 m. The results show that the last two variations have a difference in resistance force of 3.75% or below 5%.

2.4. Computation setup

At the setup stage, many things must be done in relation to determining boundary conditions in CFD simulations. This process is a process after the meshing has been completed. The parameters in the simulation process are processed at this stage such as fluid type, several types, materials, cell zone conditions, boundary conditions, mesh interfaces, dynamic mesh, reference values, solution methods, solution control, solution initialization, calculation activities, last running calculations, and setting the results after the simulation.

The speed variations on each model are 1 knot, 2 knots, 3 knots, and 4 knots. The next stage is the initial setup using double-precision, the processing options used are two parallel processors, and it uses 2 Graphics Processing Units. The type used is stable. The acceleration due to gravity on the z-axis used is 9.81. The turbulent model used is k-epsilon with two equations. The standard multiphase used is fluid volume and it uses open channel flow. The second phase is liquid water while the first phase is liquid air. While at the boundary conditions, the inlet pressure uses a bottom level of -17.811 m and the speed is according to variations. Then the pressure inlet type is multiphase. To monitor the simulation process as shown in Figure 4, it is done using plots. Open channel using the flat channel. Then the run calculation consists of a time scale factor of 0.5 and the number of iterations is 200.

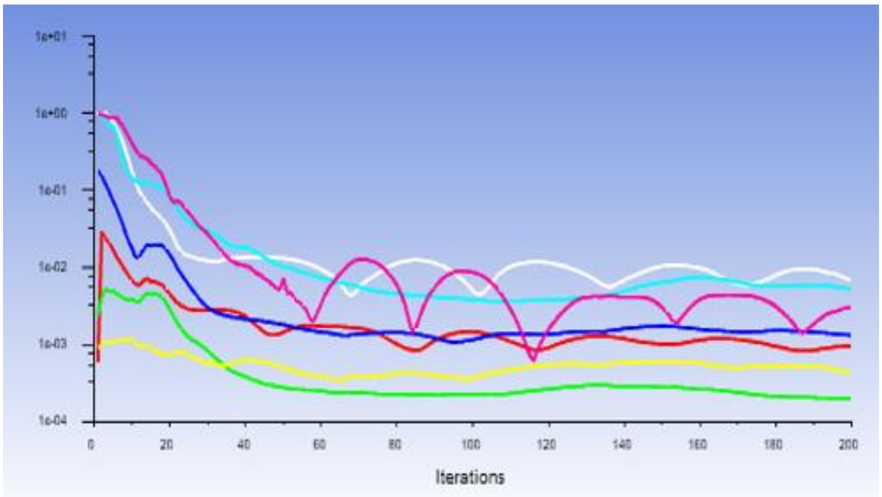
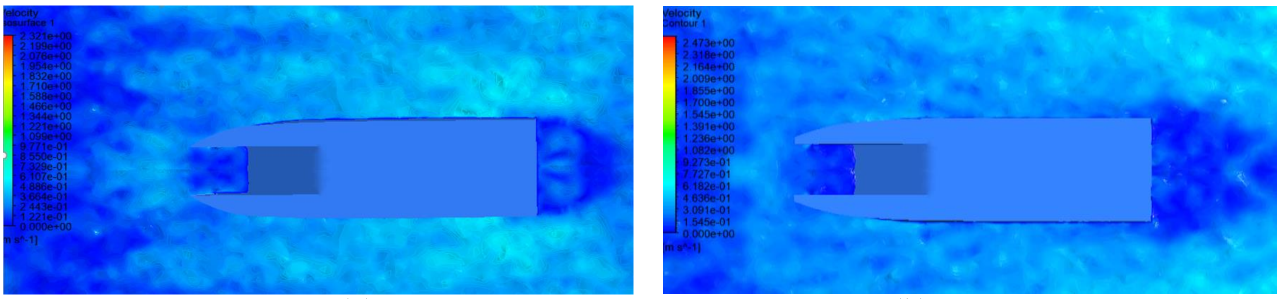


Figure 4. Computation iterations

3. Results and Discussion

3.1. Fluid flow velocity contour

The movement of fluid flows around the bow, hull, and stern on the three-ship models and conveyors at a speed of 1 knot as shown in Figure 5. Top view of fluid velocity contours on U-type monohull, inner flat hull catamaran type, and trimaran-type symmetry equipped with the conveyor on the bow as shown in Figures 5a, 5b, and 5c, respectively. The movement and velocity of fluid flow around the model are interpreted based on contours and colors. Blue means low speed, green means medium speed, yellow means high speed, and red means very high speed. The velocity of fluid flow around the conveyor can be seen in color contours between the fore two hulls.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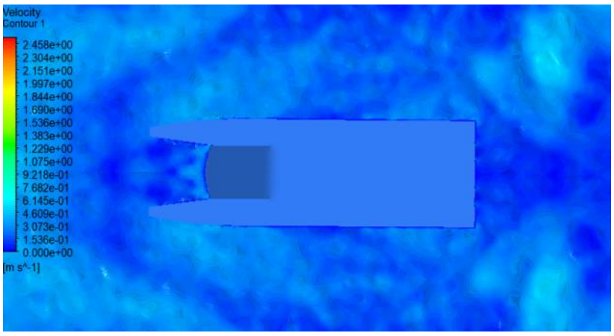
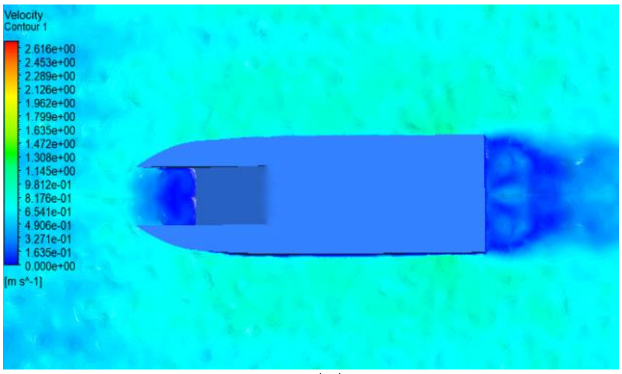


(c)

Figure 5. Fluid flow velocity contour in 1 knots speed: (a) Monohull, (b) Catamaran, (c) Trimaran

The U-type monohull has a blue contour around the conveyor. It is known that this type has a fluid flow velocity around the conveyor of 0.1221 m/s. While the flow velocity at the bow is 0.2443 m/s, then increases around the side of the ship hull by 0.3664 m/s and down at the ship stern (Figure 5a). Catamaran type Inner flat hull has a blue contour around the conveyor. This model has fluid flow velocity around the conveyor is 0.1545 m/s. Then the flow velocity at the bow is 0.3091 m/s and increases around the hull by 0.4636 m/s (Figure 5b). The contour color around the conveyor on the symmetrical trimaran model is light blue. This model has fluid flow velocity around the conveyor is 0.3073 m/s. The flow velocity at the bow is 0.3873 m/s, then increased around the hull side to 0.4609 m/s (Figure 5c)

From the comparison of the three images in Figure 5, models that make ocean waste flow to the conveyor the fastest are the symmetric trimaran, inner flat hull type catamaran, and U type monohull. This happens to cause that the faster the water moves to the conveyor, the faster the ocean waste goes to the conveyor. Because the movement of ocean waste depends on and is the same as fluids movement. So that when the ship model has a high-speed flow that comes to the conveyor, so it will collect ocean debris faster to conveyor ship.



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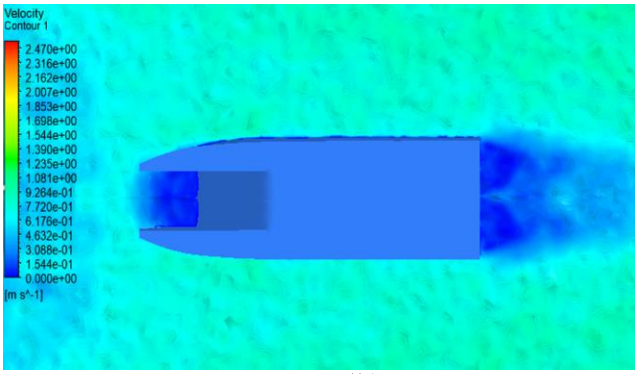

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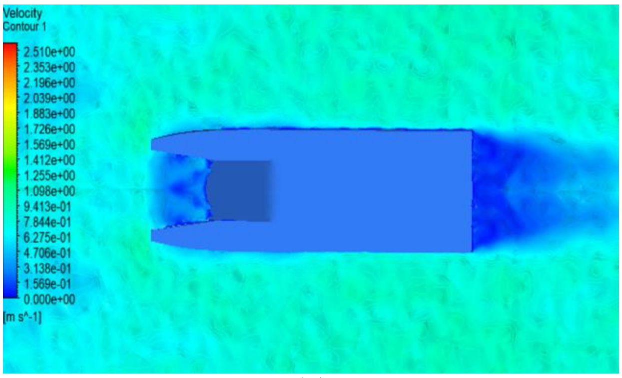
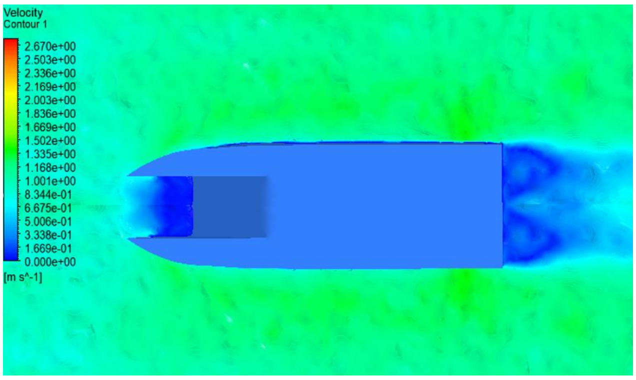


(c)

Figure 6. Fluid flow velocity contour in 2 knots speed: (a) Monohull, (b) Catamaran, (c) Trimaran

Fluid flow velocity contour in 2 knots speed for the three-ship and conveyor models as shown in Figure 6. It is known that U type monohull has a blue contour and fluid flow velocity around the conveyor is 0.1635 m/s, the flow velocity at the bow ship is 0.3271 m/s, and the flow velocity at the hull side of the model is 0.8176 m/s (Figure 6a). An inner flat hull-type catamaran has a light blue contour and fluid flow velocity around the conveyor is 0.228 m/s. Flow velocity at bow ship is 0.617 m/s, and flow velocity at hull side of the model is 0.926 m/s (Figure 6b). The symmetrical trimaran has a light blue contour and fluid flow velocity around the conveyor is 0.4706 m/s. Flow velocity at bow ship is 0.7844 m/s, and flow velocity at hull side of the model is 1.098 m/s (Figure 6c). This value is known from the color scale next to the model. From the comparison of the three images in this figure, models that make ocean waste flow to the conveyor the fastest are the symmetric trimaran, inner flat hull type catamaran, and U type monohull. This happens to cause that the faster the water moves to the conveyor, the faster the ocean waste goes to the conveyor. Because the movement of ocean waste depends on and is the same as fluids movement. So that when the ship model has a high-speed flow that comes to the conveyor, so it will collect ocean debris faster to conveyor ship.

Fluid flow velocity contour in 3 knots speed for the three-ship and conveyor models as shown in Figure 7. It is known that U type monohull has a light blue contour and fluid flow velocity around the conveyor is 0.1669 m/s, the flow velocity at the bow ship is 0.667 m/s, and the flow velocity at the hull side of the model is 1.168 m/s (Figure 7a). An inner flat hull-type catamaran has a light blue contour and fluid flow velocity around the conveyor is 0.3302 m/s. Flow velocity at bow ship is 0.825 m/s, and flow velocity at hull side of the model is 1.321 m/s (Figure 7b). The symmetrical trimaran has light blue close to green contour and fluid flow velocity around the conveyor is 0.3489 m/s. Flow velocity at bow ship is 0.8722 m/s, and flow velocity at hull side of the model is 1.570 m/s (Figure 7c).



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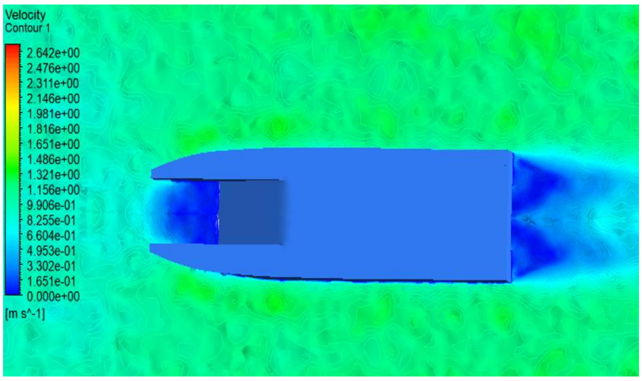

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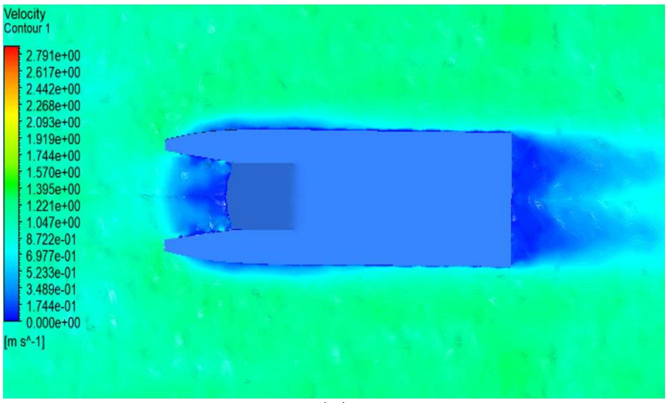
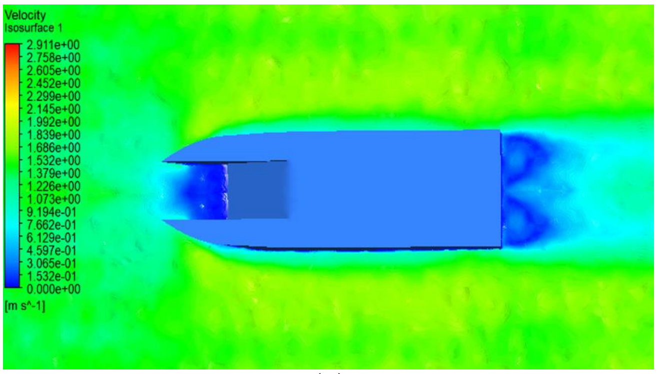


(c)

Figure 7. Fluid flow velocity contour in 3 knots speed: (a) Monohull, (b) Catamaran, (c) Trimaran

From the comparison of the three images in this figure, models that make ocean waste flow to the conveyor the fastest are the symmetric trimaran, inner flat hull type catamaran, and U type monohull. This happens to cause that the faster the water moves to the conveyor, the faster the ocean waste goes to the conveyor. Because the movement of ocean waste depends on and is the same as fluids movement. So that when the ship model has a high-speed flow that comes to the conveyor, so it will collect ocean debris faster to conveyor ship.



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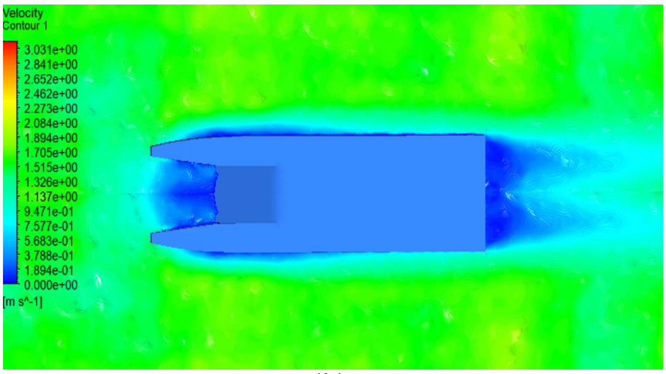

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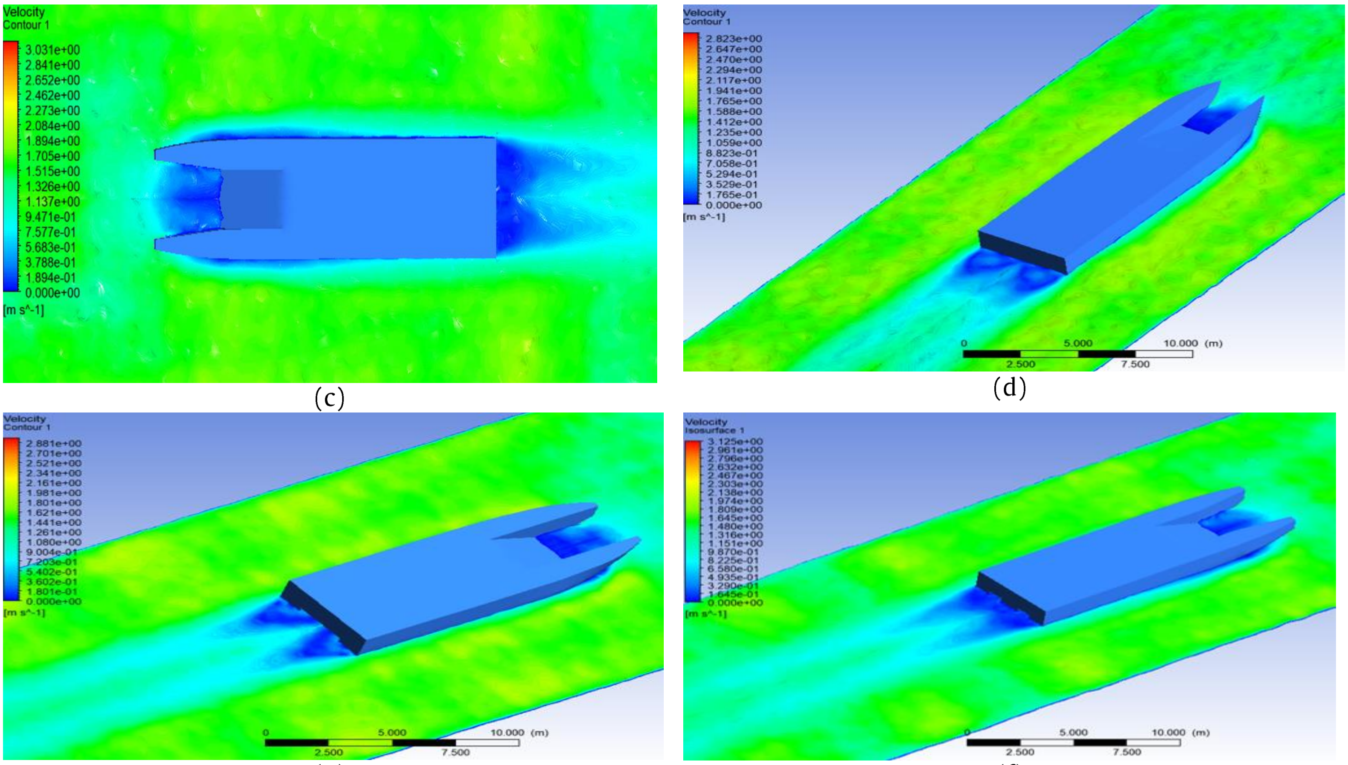


(c) (d)

(e) (f)

Figure 8. Fluid flow velocity contour in 4 knots speed: (a) Monohull, (b) Catamaran, (c) Trimaran, (d) Monohull rear view, (e) Catamaran rear view, (f) Trimaran rear view.

Fluid flow velocity contour in 4 knots speed for the three-ship and conveyor models as shown in Figure 8. It is known that U type monohull has a light blue contour and fluid flow velocity around the conveyor is 0.3065 m/s, the flow velocity at the bow ship is 0.766 m/s, and the flow velocity at the hull side of the model is 1.515 m/s (Figure 8a). An inner flat hull-type catamaran has light blue close to green contour and fluid flow velocity around the conveyor is 0.3788 m/s. Flow velocity at bow ship is 0.947 m/s, and flow velocity at hull side of the model is 1.515 m/s (Figure 8b). The symmetrical trimaran has light blue close to green contour and fluid flow velocity around the conveyor is 0.5683 m/s. Flow velocity at bow ship is 0.9471m/s, and flow velocity at hull side of the model is 1.705 m/s (Figure 8c). From the comparison of the three images in this figure, models that make ocean waste flow to the conveyor the fastest are the symmetric trimaran, inner flat hull type catamaran, and U type monohull. This happens to cause that the faster the water moves to the conveyor, the faster the ocean waste goes to the conveyor. Because the movement of ocean waste depends on and is the same as fluids movement. So that when the ship model has a high-speed flow that comes to the conveyor, so it will collect ocean debris faster to conveyor ship.

3.2. Fluid flow pattern

The fluid flow pattern is a vector of flow lines on the water surface around the model. The blue line is the fluid flow line, while the pink line is direction moving fluid. Figure 9 shows fluid flow patterns of three ship models, namely monohull type U, catamaran type inner flat hull, and trimaran type symmetrical at 1 knots speed.

Based on the direction vector in the pink line and flow on the blue line, the U type monohull has a straight flow pattern type and approaches the conveyor (Figure 9a). This makes it easy for ocean waste to collect onto the conveyor. Inner flat hull type catamaran has a straight flow pattern with a slight slope towards the conveyor (Figure 9b). This makes it easy for ocean waste to go to the conveyor, but ocean waste on the outer side will be difficult to get to the conveyor. The symmetrical trimaran has a sloping flow pattern away from the conveyor (Figure 9c). This makes it difficult for ocean waste to collect on the conveyor. From comparing the three images, it is known that the models that are easiest to bring ocean waste closer to the conveyor are U type monohull, inner flat hull type catamaran, and symmetrical trimaran, respectively. In addition, all three ships have a turbulent flow model behind the ship, this is following the *Reynolds number* in the three models [14].

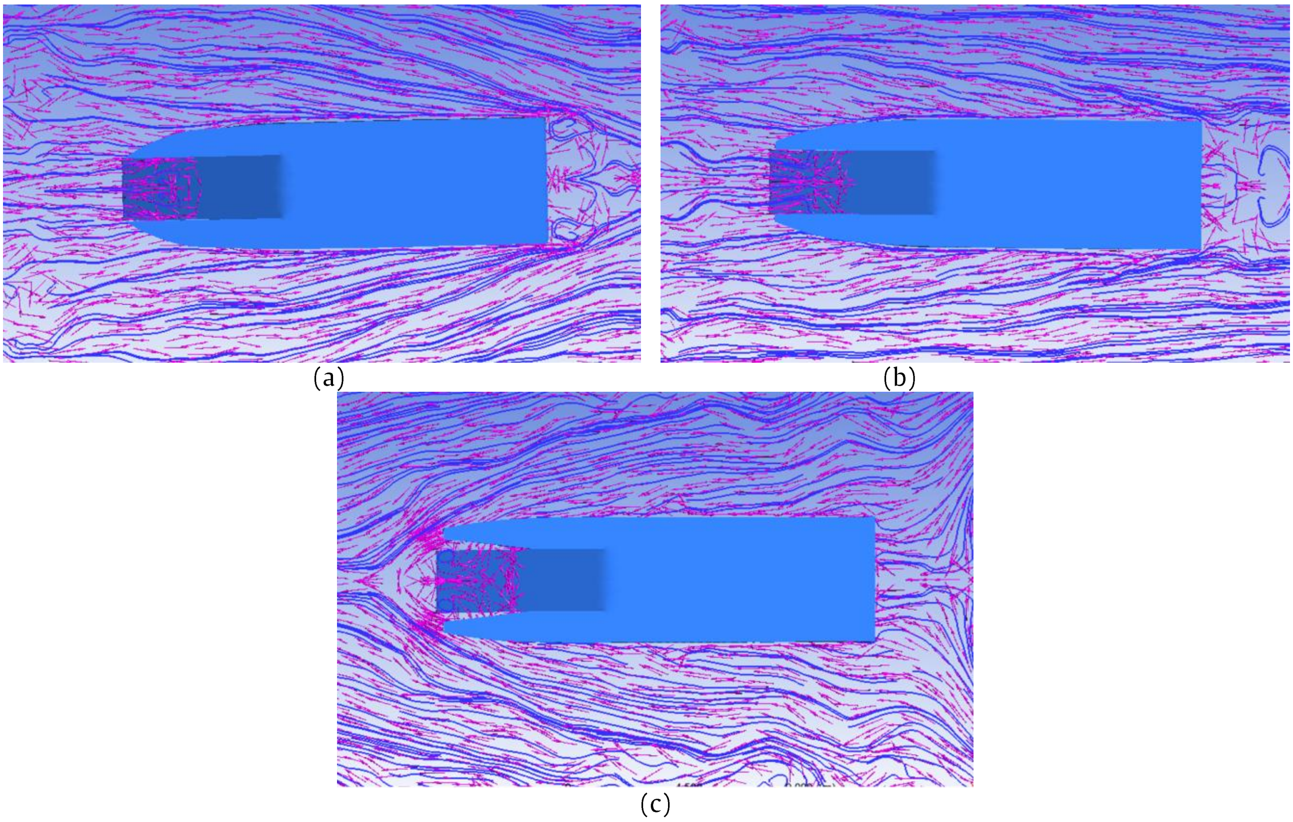


Figure 9. Fluid Flow Pattern in 1 knots speed: (a) Monohull, (b) Catamaran, (c) Trimaran

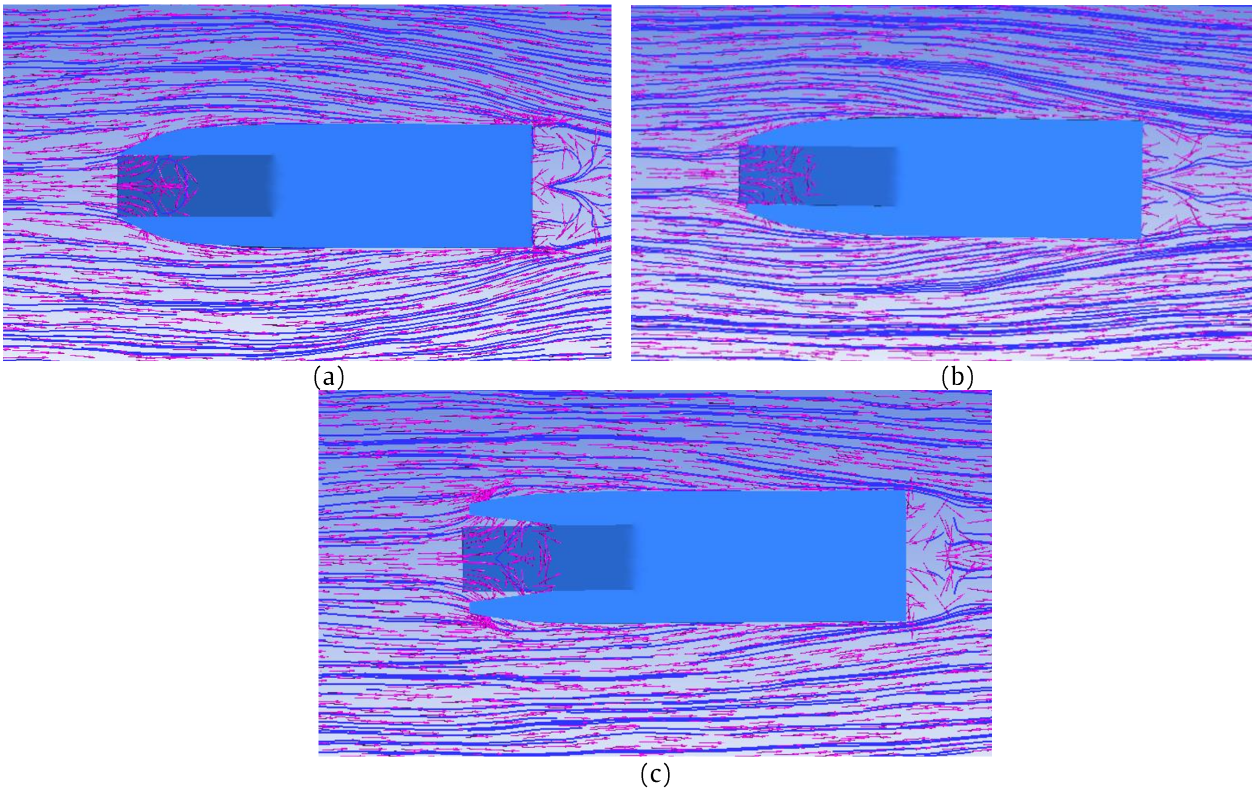


Figure 10. Fluid Flow Pattern in 2 knots speed: (a) Monohull, (b) Catamaran, (c) Trimaran

Fluid flow pattern in 2 knots speed for the three-ship and conveyor models as shown in Figure 10. Based on the direction vector in the pink line and flow on the blue line, the U type monohull has a straight flow pattern type and approaches the conveyor (Figure 10a). This makes it easy for ocean waste to collect onto the conveyor. Inner flat hull type catamaran has a sloping flow pattern away from the conveyor (Figure 10b). This makes it difficult for ocean waste to collect on the conveyor. The symmetrical trimaran has a straight flow pattern with a slight slope towards the conveyor (Figure 10c). This makes it easy for ocean waste to go to the conveyor, but ocean waste on the outer side will be difficult to get to the conveyor. From comparing the three images, it is known that the models that are easiest to bring ocean waste closer to the conveyor are U type monohull, symmetrical trimaran, and inner flat hull type catamaran, respectively. In addition, all three ships have a turbulent flow model behind the ship, this is following the Reynolds number in the three models [14].

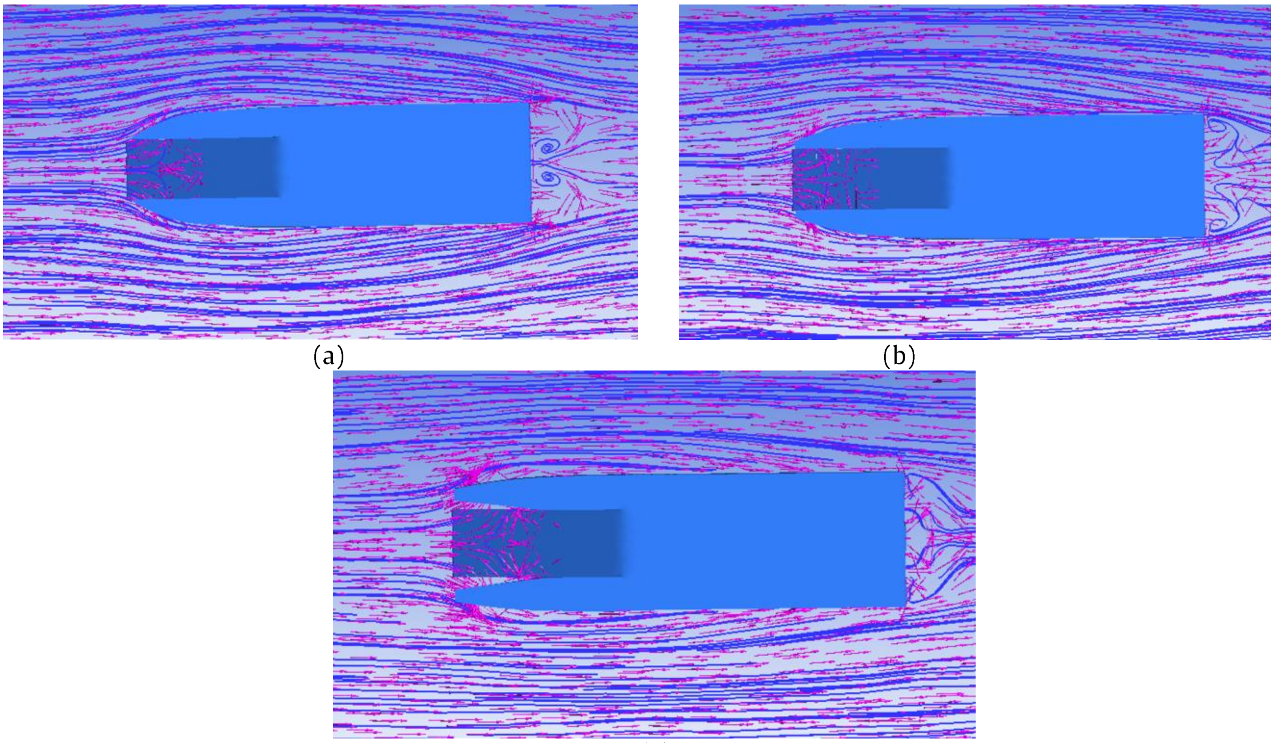
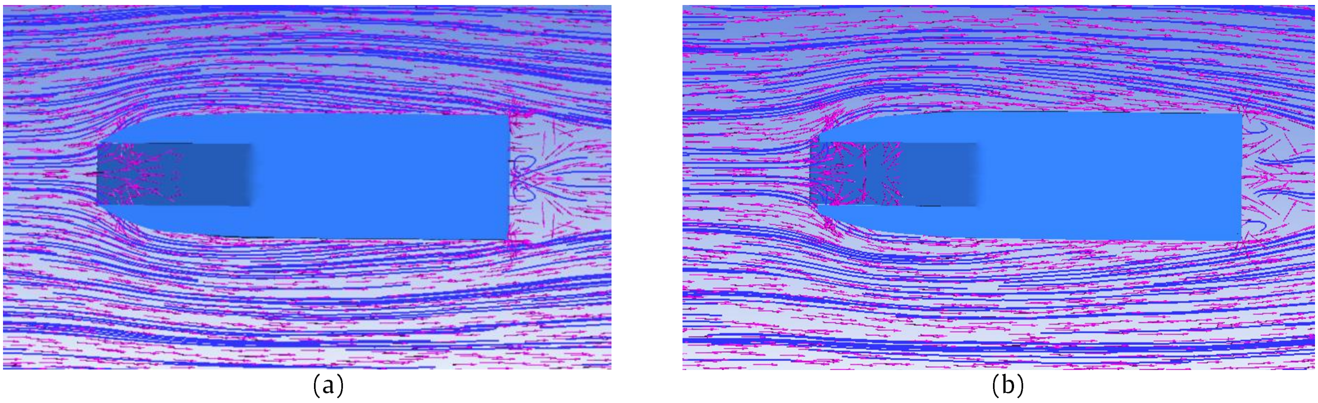


Figure 11. Fluid Flow Pattern in 3 knots speed: (a) Monohull, (b) Catamaran, (c) Trimaran

Fluid flow pattern in 3 knots speed for the three-ship and conveyor models as shown in Figure 11. Based on the direction vector in the pink line and flow on the blue line, the U-type monohull has a straight flow pattern with a slight slope towards the conveyor (Figure 11a). This makes it easy for ocean waste to go to the conveyor, but ocean waste on the outer side will be difficult to get to the conveyor. Inner flat hull type catamaran has a sloping flow pattern away from the conveyor (Figure 11b). This makes it difficult for ocean waste to collect on the conveyor. The symmetrical trimaran has a straight flow pattern type and approaches the conveyor (Figure 11c). This makes it easy for ocean waste to collect onto the conveyor. From comparing the three images, it is known that the models that are easiest to bring ocean waste closer to the conveyor are symmetrical trimaran, U type monohull, and inner flat hull type catamaran, respectively. In addition, all three ships have a turbulent flow model behind the ship, this is following the Reynolds number in the three models [14].



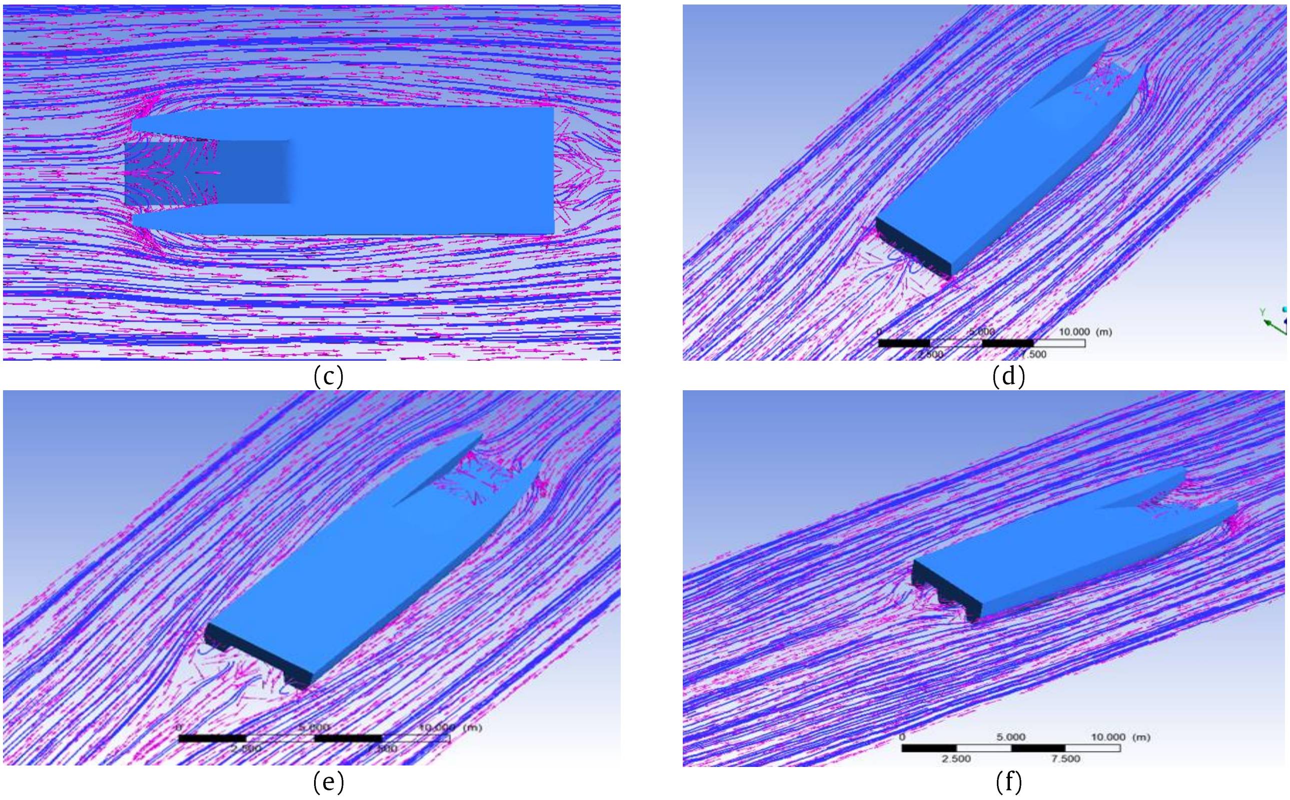


Figure 12. Fluid Flow Pattern in 4 knots speed: (a) Monohull, (b) Catamaran, (c) Trimaran, (d) Monohull rear view, (e) Catamaran rear view, (f) Trimaran rear view

Fluid flow pattern in 4 knots speed for the three-ship and conveyor models as shown in Figure 12. Based on the direction vector in the pink line and flow on the blue line, the U-type monohull has a straight flow pattern with a slight slope towards the conveyor (Figure 12a). This makes it easy for ocean waste to go to the conveyor, but ocean waste on the outer side will be difficult to get to the conveyor. Inner flat hull type catamaran has a sloping flow pattern away from the conveyor (Figure 12b). This makes it difficult for ocean waste to collect on the conveyor. The symmetrical trimaran has a straight flow pattern type and approaches the conveyor (Figure 12c). This makes it easy for ocean waste to collect onto the conveyor. From comparing the three images, it is known that the models that are easiest to bring ocean waste closer to the conveyor are symmetrical trimaran, U type monohull, and inner flat hull type catamaran, respectively. In addition, all three ships have a turbulent flow model behind the ship, this is in accordance with the Reynolds number in the three models [14].

3.3. Resistance Force

The resistance force is on the U-type monohull model is shown in Table 2, the inner flat hull type catamaran is shown in Table 3, and symmetrical trimaran is shown in Table 4. Speed variations are 1 knot, 2 knots, 3 knots, and 4 knots. This calculation uses body sizing and face sizing sizes, namely 0.4 m and 0.3 m. Face sizing mesh is used for ship and conveyor models, while body sizing mesh is used for other domains.

Table 2. Monohull resistance

Speed	Body sizing (m)	Face sizing (m)	Number of element	Resistance (N)
1 knot	0.4	0.3	675360	322.498
2 knot	0.4	0.3	675360	1375.834
3 knot	0.4	0.3	675360	3349.800
4 knot	0.4	0.3	675360	6018.020

Table 3. Catamaran resistance

Speed	Body sizing (m)	Face sizing (m)	Number of element	Resistance (N)
1 knot	0.4	0.3	701403	433.796
2 knot	0.4	0.3	701403	1572.670

3 knot	0.4	0.3	701403	3834.160
4 knot	0.4	0.3	701403	7273.180

Table 4. Trimaran resistance

Speed	Body sizing (m)	Face sizing (m)	Number of element	Resistance (N)
1 knot	0.4	0.3	7745364	704.422
2 knot	0.4	0.3	7745364	1926.336
3 knot	0.4	0.3	7745364	3991.54
4 knot	0,4	0.3	7745364	7643.2

From the comparison of the three tables, it is known that the faster the model, the larger the resistance force. Then successively the resistance force from the smallest to the largest are U-type monohull, inner flat hull type catamaran, and symmetrical trimaran.

4. Conclusion

This study provides information on the effect of using conveyor technology on the number of different ship hulls on the effects of marine debris collection is still scarce. Selection of the appropriate number of hull ships for ocean waste collection is carried out, types of hull ship models used are monohull type U, catamaran type inner flat hull, and trimaran type symmetrical. The numerical simulation is based on Reynolds Averaged Navier Stokes (RANS) in CFD. The speed variations on each model are 1 knot, 2 knots, 3 knots, and 4 knots. From the comparison of the three models in fluid flow velocity contour, models that make ocean waste flow to the conveyor the fastest are the symmetric trimaran, inner flat hull type catamaran, and U type monohull. Then, from the comparison of the three models in the fluid flow pattern, models that are easiest to bring ocean waste closer to the conveyor are U type monohull, symmetrical trimaran, and inner flat hull type catamaran, respectively. While from the comparison resistance force of the three models, successively the resistance force from the smallest to the largest are U-type monohull, inner flat hull type catamaran, and symmetrical trimaran.

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