EFFECT OF CATAMARAN HULL TYPE ON OCEAN WASTE COLLECTION BEHAVIOR

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ABSTRACT

In this paper an attempt has been made to assess how effective waste-collecting use catamaran ship with conveyor in the front. Numerical investigation based on Reynolds Averaged Navier Stokes (RANS) for predicting the flow pattern characteristics, velocity contour, and ship resistance. The focus of the present study is the impact of catamaran ship hull front shape on waste collection in calm water through the numerical methods. The three variations of the front of the hull used are symmetrical hull type, inner flat, and outer flat. It is done using speed variations of 1 to 4 knots. The results show inner flat hull catamaran has the smallest total resistance value than others. In addition, analysis of the flow pattern in front of catamaran shows that outer flat hull catamaran is the easiest to make waste closer to conveyor. From analysis of velocity contours shows that outer flat hull catamaran also has fastest to make the waste close to conveyor.

Keyword: Waste collection, catamaran hull type, CFD, flow pattern, velocity contour, ship resistance.

Introduction

Waste in the sea especially plastic and solid waste are becoming global worries. Plastic is sea waste majority in the Western North Pacific (33%), Indian Ocean (31%) and Eastern North Pacific (25%) [1]. Floating objects like plastic can be easily transported by wind, waves and surface currents and become spread quickly in the sea [2]. Marine wastes have in all sizes from debris micrometres until millimetres, middle-sized wastes less than one meter long like plastic bags and soda bottles and in tens meters in length such as pieces of wrecked vessels and lost cargo containers [3]. There were an approximate 32 million tonnes of unmanaged plastic waste in coastal zones worldwide in 2010, producing in between 4.8 and 12.7 million tonnes of plastic waste flow from land into oceans that year. Forecasting from this condition, the total mass of plastic in 2025 will add between 100 and 250 million tonnes with same business assumption [4]. China and Indonesia made the largest contributor to plastic waste in the sea in the world, first and second in the sequence [5]. Various studies have allowed ships to play a role in the collection and processing of marine debris [6]. The initial design of the monohull vessel for collecting marine debris on the island area was also proposed [7]. Including studies on the use of digital technology to involve communities around the sea to reduce marine debris [8].

Research on the conveyor wing shape type effect on ocean waste collection behavior was investigated by Sugianto al [9], the result showed that the circle wing holes are faster in collecting garbage. Research on effect of portable conveyor placement in ship on ocean waste collection behavior was done by Sugianto el al [10], the results show that the conveyor on the bow model is the easiest to get the ocean waste closer to the conveyor. This model also produces the smallest ship resistance compared to other models. Then experimental research regarding the shape of the wing conveyor shows that the circle hollow wing model 18.75 cm 60 degree has a higher marine debris collecting ratio than other models [11]. Also, it is suggested to operate the device at a low speed because the collected AMD ratio is high and the lost AMD ratio is small [12].

Research on catamarans generally does not use a conveyor such as analysis of the smallest ship resistance due to differences in the shape of the catamaran hull [13]. Research on resistance and flow distribution in catamarans due to differences in ship shape. Research on the distance of the catamaran hull to the effect of ship resistance [14]. Research on the effect of the number of hulls on marine debris collection has been investigated [15-16]. The results show that the catamaran is the best in collecting marine debris.

However, no one has researched the type of catamaran that is most suitable for waste collection. Besides that, tools or systems for collecting marine debris using catamarans are beginning to be discovered [17], but research on conveyor-mounted catamarans is rare, especially related to hydrodynamic analysis in resistance force and flow distribution and ocean waste collection behavior.

In this paper, an attempt made to assess how effective waste-collecting use catamaran ship with conveyor in the front. Numerical investigation based on Reynolds Averaged Navier Stokes (RANS) for predicting the flow pattern characteristics that are used to analyze how easy it is for waste to approach the conveyor, velocity contour which is used to analyze how fast the garbage is approaching the conveyor, and ship resistance which will affect the power ships and fuel consumption. The focus of the present study is the impact of catamaran ship hull front shape on waste collection in calm water through the application of numerical methods. The three variations of the front of the hull used are symmetrical hull type, inner flat, and outer flat.

Methodology

The ship data used for this research are catamaran ship data and conveyor data as shown in Table 1.

Table 1. Ship main dimension [7] [18]

Type	Ship dimension
Length overall, Loa	16.223 m
Length of water line, Lwl	15.431 m
Maximum breadth, B	4.8 m
Height, H	2.38 m
Draft, T	1.2 m
Conveyor length	6.5 m
Conveyor angle	20°
Conveyor wide	2.4 m
Speed variations	1, 2, 3, 4 knots
Crew	4 persons

A variation on this model is the shape of the catamaran hull. There are three models of catamarans, namely symmetrical hull type, inner flat, and outer flat. The governing equation of the flow around the ship is expressed using the incompressible Reynolds Average Navier Stokes (RANS) equations:

$$\nabla.(\rho u) = 0 \tag{1}$$

$$\rho \bar{u}_j \frac{\partial \bar{u}_j}{\partial x_j} = \rho \bar{f}_i + \frac{\partial}{\partial x_j}\left[-\bar{p}\delta_{ij} + \mu\left(\frac{\partial \bar{u}_j}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i}\right) - \rho\overline{u_i' u_j'}\right. \tag{2}$$

The catamaran has a conveyor mounted at the front of the hull. Then, the view catamaran model used in this research is as shown in Figure 1. It shows the front and 3D of the catamaran models. The main dimensions of catamaran of all three models are the same, but the difference is in the curvature of the hull. This variation was carried out to determine the effect of catamaran type on the behavior of collecting marine debris and the resistance force. Information on the ship and conveyor used in this model is presented in Table 1. This data was taken from previous research on ocean waste collection ships for Surabaya Sea [7]. The conveyor data was taken from product catalogs of Dorner conveyor industry project guide with the Aquapruf 7400 series [18].

(a)

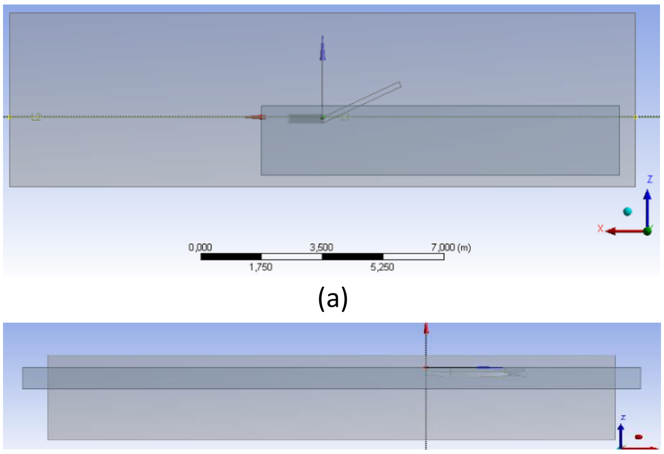
(b)

(c)

Figure 1. Catamaran type: (a) Symmetric hull, (b) Outer flat hull, (c) Inner flat hull

The dimensions of the fluid domain are based on the recommendations of Versteeg and Malalasekera [19] as shown in Figure 2. The distance from the front domain boundary to the bow is L, the distance from the stern to the rear side is 4L, the distance from the side of the model to the sidewall is 0.4 L, the distance from the keel of the model to the underside is L, and the distance from the top of the model to the sides above is 0.2 L. Boundary conditions at the model are determined as non-slip conditions. Inlet is a section that located in the fluid domain section in front of bow ship. This is used as an initial location of flow entry to tunnel. Outlet is a back area of model. This area is the location where the fluid gets out of tunnel. Hull is a model object that is subjected to the fluid and is located within the tunnel, while the symmetry is the area that signifies half of tunnel modeled in this simulation.

Setting process is process of entering the parameter of tank and fluid in numerical simulation. The process includes models, materials, cell zone conditions, boundary conditions, mesh interfaces, dynamic mesh, reference values, solution methods, solution controls, solution initialization, calculation activities, and the last is run calculation.



(a)

(b)

Figure 2. Fluid domain: (a) Side view, (b) Top view

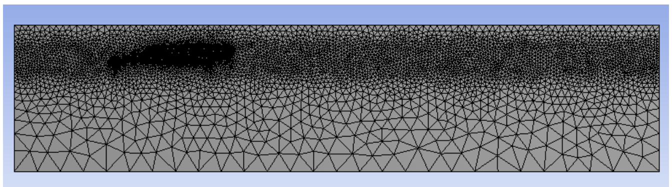


Figure 3. Mesh generate in computational domain

Domain computation and mono hull ship model using structured hexahedral as shown in Figure 3. Then, tested of numerical results that have been obtained. Test conduct by using a different number of elements. The difference of elements number is approximately 1.5 until 2 times from the previous calculation [20]. Grid independence test is carried out to get optimal between cells number and solver running time. It due to limitations of computer processor used in the solver calculation. Then, the error tolerance or difference between one result and the next is below 5%.

The root-mean-square (RMS) criteria used to check the convergence with a residual target value (variable value) reaching 10-5. These residual monitors demonstrate monotonic convergence, indicating a well-posed problem and a tightly converged solution [21].

Result and Discussion

The results obtained are velocity contours, flow patterns, and resistance on each catamaran type waste collection ship model with conveyors.

Figure 4 shows the velocity contours obtained. From the figure, what can be seen is the fluid velocity around the conveyor, so it can be estimated which type of catamaran that makes the ocean waste closing faster to the conveyor. Next, flow patterns result is as shown in Figure 5, from this picture it can be seen which type of catamaran that makes ocean waste be easier in approaching the conveyor. Furthermore, it can also be known how the resistance performance is on each catamaran type waste collection ship model using conveyors in front side, and lastly the variations in ship speed are 1,2,3, and 4 knot.

From the comparison of speed contours of three models of catamaran at 1 until 4 knots speed in Figure 4, it is known that water area in front of the catamaran inner flat hull has a dark blue color with a square pattern between the demihull, with the average velocity contour of water in front of the conveyor being 0.1 m/s, 0.15 m/s, 0.296 m/s, and 0.369 m/s, respectively.

The water area in front location of the catamaran outer flat hull has blue color with a W pattern and has an average velocity contour color of 0.17 m/s, 0.3 m/s, 0.427 m/s, and 0.543 m/s, respectively.

While water area in front of the catamaran symmetry hull has a dark blue color with a W pattern. It has a velocity contour with an average of 0.15 m/s, 0.2779 m/s, 0.3772 m/s, and 0.521 m/s, respectively. From results above, it can be seen that the catamaran outer flat hull is the fastest in collecting waste, while the catamaran inner flat hull is the slowest in collecting waste.

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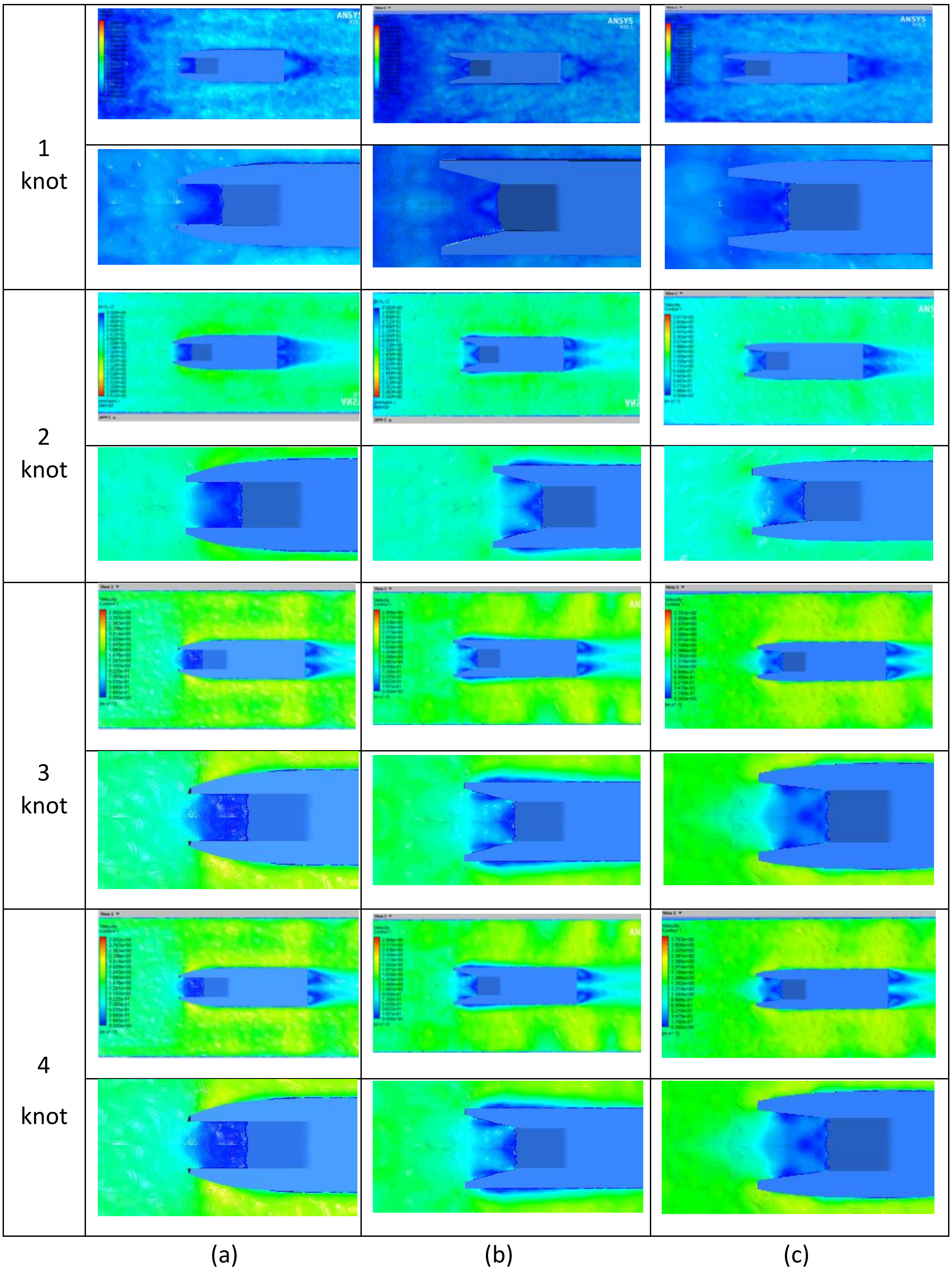

Figure 4. Velocity contour in 2 knot speed: (a) inner flat hull, (b) outer flat hull, and (c) symmetry hull

with the average velocity contour of water in front of the conveyor being 0.1 m/s, 0.15 m/s, 0.296 m/s, and 0.369 m/s, respectively. Furthermore, the water area in front location of the catamaran outer flat hull has blue color with a W pattern and has an average velocity contour color of 0.17 m/s, 0.3 m/s, 0.427 m/s, and 0.543 m/s, respectively. While water area in front of the catamaran symmetry hull has a dark blue color with a W pattern. It has a velocity contour with an average of 0.15 m/s, 0.2779 m/s, 0.3772 m/s, and 0.521 m/s, respectively.

From results comparison, it can be seen that the catamaran outer flat hull is the fastest in collecting waste, while the catamaran inner flat hull is the slowest in collecting waste.

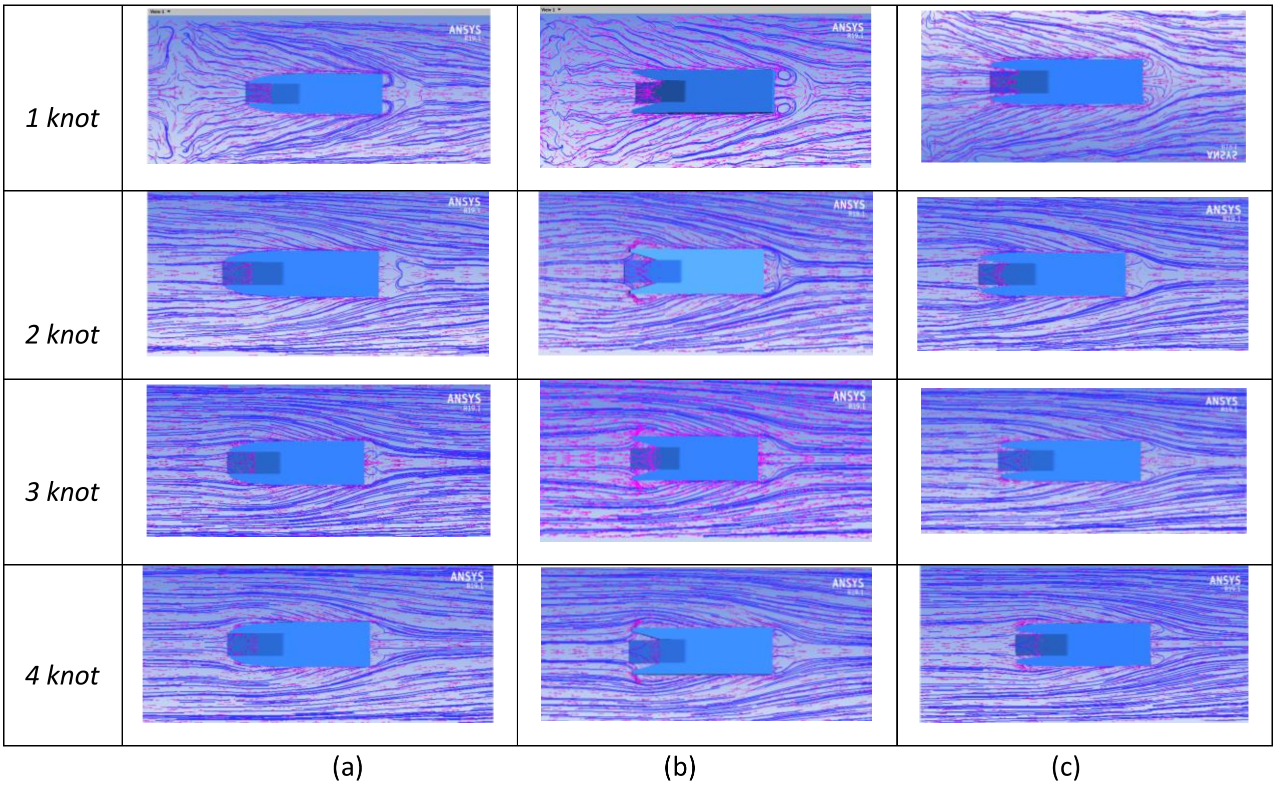

Figure 5. Flow patterns in 1 knot speed: (a) inner flat hull, (b) outer flat hull, and (c) symmetry hull

Comparison of flow patterns of three models of catamaran at 1 until 4 knots speed are in Figure 5. It is known that the water area in front of the catamaran inner flat hull has a forward-facing U-shaped flow pattern, but at high speed it becomes a triangular shape. Further, the waters in front of the location of the catamaran outer flat hull have a box-shaped flow pattern, while the water area in front of the catamaran symmetry hull has a U-shaped flow pattern facing backward. From the results above, it can be seen that outer flat hull catamaran is the easiest to collect waste because it has a box-shaped flow pattern that makes the garbage could moves straight from the front and gets closer to the conveyor.

Furthermore, symmetric hull catamaran, because it has a U-upside down flow pattern, it makes it easier for garbage to be collected on the conveyor, while the inner flat hull catamaran is the most difficult to collect garbage because the waste is spreading outside the conveyor. Reynolds number is a parameter that can be used to determine the type of fluid around an object. In general, there are three types of flow in fluids, namely laminar, transitional, and turbulent. Based on Figure 5, it is known that all types of catamarans and all speeds will produce a turbulent flow behind the ship [22].

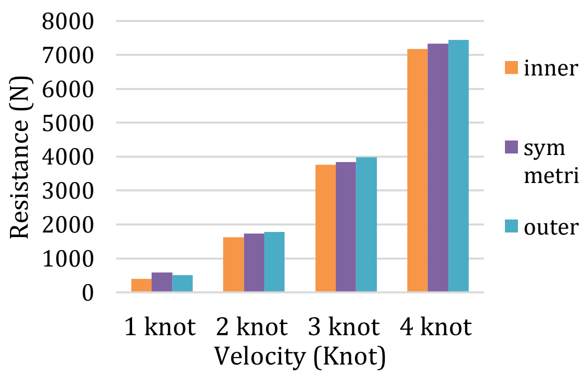

Figure 6. Resistance comparison

From comparison in Figure 6, it can be seen that resistance of catamaran with conveyor from the largest to the smallest is outer flat hull catamaran, symmetry hull catamaran, and inner flat hull catamaran, respectively. The difference in resistance at a speed of 4 knots between outer flat hull catamaran and inner flat hull catamaran is 3.71%, the difference between outer flat hull catamaran and symmetry of the catamaran hull is 1.57%.

Conclusion

Three variations in shape of catamaran were investigated by using numerical methods. From the analysis of velocity contour, the outer flat hull catamaran has faster in collecting waste, while the catamaran inner flat hull has the slowest in collecting waste. From the flow pattern analysis, the outer flat hull catamaran is the easiest to collect waste. Then inner flat hull catamaran, because it has a forward-facing U flow pattern, makes it easy for garbage to collect on the conveyor. Symmetric hull catamaran is the most difficult to collect garbage because the waste spreads outside the conveyor. Resistance of catamaran with conveyor from the largest to the smallest is outer flat hull catamaran, symmetry hull catamaran, and inner flat hull catamaran, respectively.

References

[1] S. Chiba, H. Saito, R. Fletcher, T.Yogi, M. Kayo, S. Miyagi, M. Ogido, K. Fujikura. Human footprint in the abyss: 30 year records of deep-sea plastic debris. Mar. Policy **98** (2018) 204–212. https://doi.org/10.1016/j.marpol.2018.03.022

[2] Bergmann, M.; Tekman, M.B.; Gutow, L. Marine litter: Sea change for plastic pollution. Nature **544** (2017) 297. https://doi.org/10.1038/544297a

[3] UNEP. Marine Litter Vital Graphics. 2016. https://www.grida.no/publications/60 (accessed December 20, 2022).

[4] IPCC. Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects; Cambridge University Press: Cambridge, UK, 2014.

[5] J. R. Jambeck, A. Andrady, R. Geyer, R. Narayan et al. Plastic waste inputs from land into the ocean. Science **374** (2015) 768-771. https://doi.org/10.1126/science.1260352

[6] E. Sugianto, J.H. Chen. Ships for waste management in Indonesian seas: Contexts and challenges. In Proceedings of the 12th International Indonesia Forum Conference: Rising to the Occasion: Indonesian Creativity, Ingenuity, and Innovation in a World in Transition, Tainan, Taiwan, 26–27 June 2019.

[7] E. Sugianto, J.H. Chen. Preliminary concept of ship use to waste management in sea shallow water. In Proceedings of the 33th Asian-Pacific Technical Exchange and Advisory Meetings on Marine Structures (TEAM 2020), Tainan, Taiwan, 14–17 October 2019.

[8] E. Sugianto, J.H. Chen. Buy marine debris: A digital platform for sustainable marine debris management involving fishermen. Int. J. Humanit. Soc. Sci. **3** (2021) 36-48. https://doi.org/10.6936/NIJHSS.202106_3(1).0003

[9] E. Sugianto, J. H. Chen, and N. P. Purba. Numerical investigation of conveyor wing shape type effect on ocean waste collection behavior. E3S Web of Conferences **324** (2021) 01005. https://doi.org/10.1051/e3sconf/202132401005

[10] E. Sugianto, J. H. Chen, R. Sugiono, H. Prasutiyon. Effect of portable conveyor placement in ship on ocean waste collection behavior. IOP Conference Series: Earth and Environmental Science **1095** (2022) 012015.

[11] https://iopscience.iop.org/article/10.1088/1755-1315/1095/1/012015/meta

[12] E. Sugianto, J. H. Chen. Hollow Wing Technique to Enhancing Conveyor Performance on Marine Debris Collection. EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy **9**(4) (2020) 1160-1167. https://catalog.lib.kyushu-u.ac.jp/opac_download_md/6625727/p1160-1167.pdf

[13] E. Sugianto, J. H. Chen. Experimental Study of the Effect of a Solid Wing Conveyor on Marine Debris Collection. Journal of Marine Science and Technology 30 (6) (2022) 278-286. https://doi.org/10.51400/2709-6998.2584

[14] D. Chrismianto, B.A. Adietya, Y. Sobirin. Pengaruh variasi bentuk hull kapal catamaran terhadap besar hambatan total menggunakan CFD (The effect of variations in the hull shape of a catamaran on the total resistance using CFD). Kapal J. Mar. Sci. Technol. **11** (2014) 99–106. https://doi.org/10.14710/kpl.v11i2.7367

[15] A. I. Wulandari, W. R. Setiawan, T. Hidayat, and A. Fauzi. 2021. Design of Trash Skimmer Boat for Inland Waterways in East Kalimantan. Wave: Jurnal Ilmiah Teknologi Maritim **14 (**1) (2021) 9–18. https://doi.org/10.29122/jurnalwave.v14i1.4087

[16] E. Sugianto, J.-H. Chen, and N.V.A Permadi, Effect of Monohull Type and Catamaran Hull Type on Ocean Waste Collection Behavior Using OpenFOAM, Water **14** (17) (2022) 2623. https://doi.org/10.3390/w14172623

[17] E. Sugianto, A. Winarno, R. Indriyani, and J.-H.Chen. Hull number effect in ship using conveyor on ocean waste collection. Kapal: Jurnal Ilmu Pengetahuan dan Teknologi Kelautan **18** (3) (2021) 128–139. https://doi.org/10.14710/kapal.v18i3.40744

[18] E. Sugianto, J.-H. Chen, and N.P. Purba. Cleaning technology for marine debris: a review of current status and evaluation, Int. J. Environ. Sci. Technol (2022). doi:10.1007/s13762-022-04373-8.

[19] Dorner MFG Corp. Full specification dorner aquapruf aquagard, doner move fast and smart. 2009.

[20] H.K. Versteeg, W. Malalasekera. An Introduction to Computational Fluid Dynamics -The Finite Volume Method (2nd ed.). Pearson Education Limited, England (2007).

[21] Anderson. Computational Fluid Dynamics: The Basics with Applications (1995)

[22] ANSYS. ANSYS CFD-Solver Theory Guide. Canonsburg, PA, USA.: AnsysInc (2020)

[23] United States Navy. Resistance and powering of ships (2002).