Resistance Comparison of Flat Plate and Conventional Streamline Vessel

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Abstract. There was a phenomenal vessel which has unique hull shape, the shape of the hull is flattened not conventional streamlined as normal vessel. This phenomenal design is dedicated for small vessels such as fishing vessel, patrol vessel and a prototype has been built. This design raised a question regarding the resistance compared to conventional streamline vessel. This paper compares a flat plate vessel with 282.56 ton displacement with a conventional vessel with same displacement and same speed. The resistance comparison was conducted using Computational Fluid Dynamic (CFD) on each ship with speed range 5-10 knots of operational speed. The results of the CFD shows that the resistance of flat plate ship is higher compared to conventional vessel for 5 knots speed. The resistance value for 5 knots of flat plate vessel is 11,618 kN while the conventional vessel shape is 9.23kN. While for 10 knots speed, the flat plate vessel is also higher compared to conventional vessel with 54.53 kN for flat plate and 49.96 kN for conventional vessel.

1. Introduction
Ship is one of the important transportation in various sectors of life. So, it needs to be developed or innovated to get a ship design that is safe, efficient, and profitable in economic and operational terms. One of the innovations that currently being developed is flat plate vessels. Flat plate vessels are ships that are flat on all sides and have an axe bow hull with semi-trimaran design on the hull that forms the letter W, thus providing the benefit to the ship, first, it can break the sea waves so that the ship is more stable and wave flow toward the propeller at the rear is expected to help increase the trust of the ship. There are claims that flat plate vessels have several advantages when compared to streamline vessels such as, flat plat ships are more efficient, more stable [1] [2] [3]. These claims certainly requires further research considering the ship is contradictive to common ship design that has been widely used. The common ship design is streamline vessel which has been used in very long time in centuries.

Figure 1 Flat Plate Ship
One of the claims is the speed is higher compared to conventional hull the same power [4] [5]. The previous experiment was conducted in a tank where the model was pulled by a line connected to a pulley and the force measured. The previous research compared Flat Plate vessel and Conventional streamline vessel as shown by Table 1.

| Principal Dimension Model Comparison |
|--------------------------------------|
| **Flat Plate** | **Conventional** | **Unit** |
| Displacement | 4 | 4 | kg |
| LWL | 90 | 90 | cm |
| B | 22.5 | 22.5 | cm |
| T | 7.8 | 5.3 | cm |
| Cp | 0.597 | 0.788 |
| Cb | 0.305 | 0.489 |

The setup of the previous experiment can be shown by Figure 2.

![Figure 2 Experimental Setup](image)

Based on the experiment the measurement results shown by Figure 3, the results show that streamline vessel generates higher resistance compared to flat plate vessel.

![Figure 3 Previous Experimental Results](image)
The sentence *flat datar* mentioned in the previous paper means flat plate. This paper offers a full scale resistance comparison using Computational fluid dynamic (CFD) to compare both of the vessel in order to provide alternative perspective view.

2. Method
Ship resistance is the oncoming ship will get resistance which are opposite to the direction of the ship’s motion [7] [8]. CFD method has been widely used in ship resistance prediction[9] [10], this paper also used CFD to compare both of the vessel resistance. The software used in this paper is Numeca Fine Marine which has been used in ship performance prediction[11]. In order to provide equal and fair comparison, this paper would like to use the same displacement for both vessel.

2.1. Principal Dimension and Design
The comparison of both vessels is provided in Table 2, it can be concluded that the displacement, Draft, Block coefficient (Cb) and breadth (B) of both vessel is equal.

|                  | Flat Plate | Conventional | Unit |
|------------------|------------|--------------|------|
| Displacement     | 289.5      | 289.6        | ton  |
| LWL              | 31         | 33.25        | m    |
| B                | 7.9        | 7.82         | m    |
| T                | 3          | 3            | m    |
| Cp               | 0.705      | 0.663        |      |
| Cb               | 0.384      | 0.388        |      |

The design of the flat plate vessel are derived from many sources in papers such as [3] [5] and built in Maxsurf software, the generated 3D model can be shown by Figure 4. While the conventional streamline 3D model can be shown in Figure 5.

2.2. Ship Motion
A ship has 6 degree of freedom (DOF) motion which occurs in all ship during its voyage. There are three translation motions and three rotational motions where the illustration of 6 DOF can be shown in Figure 6 [12].
The value of pitch motion is based on the clockwise rotation; if the rotation is according clockwise the value of pitch is positive (+) and in contrary the value is negative (−).

2.3. Resistance Prediction

The resistance prediction was measured using CFD where both are using same speed variation ranging from 5 knots to 10 knots. The domain setup is based on the Table 3 and the setup of each field can be shown by Figure 7 [13] [14].

| Upstream to the Hull                  | 2Lpp |
|--------------------------------------|------|
| Downstream to the hull               | 5Lpp |
| Tank wall to the midsection          | 3Lpp |
| The height of the top surface from waterline | 0.4Lpp |

The setup results in Numeca fine marine can be shown in Figure 8 and the meshing perimeters has found no concave, negative or twisted cell as shown by Table 4.
Meshing is one important issue in CFD where some parameters must be check such as negative cells. Mapping between the physical coordinate \((x - y)\) and the natural coordinate \((\xi - \eta)\) for a heavily volumetrically distorted elements leads to mapping of an area outside of the physical element into an interior area in the natural coordinates as shown by Figure 9 [15]. For concave elements, there are areas outside the elements which will be transformed into coordinate system, this concave element volume integration will results in negative value. The model built in this paper has shown no negative cells.

| Parameter    | Flat Plate | Conventional |
|--------------|------------|--------------|
| Concave      | 0          | 0            |
| Negative Cell| 0          | 0            |
| Twisted      | 0          | 0            |

While the number of cells and vertices can be shown in Table 5.

|                     | Flat Plate | Conventional |
|---------------------|------------|--------------|
| Total Number cells  | 4,194,160  | 4,453,538    |
| Total Number Vertices| 4,425,448  | 4,690,360    |
3. Results and Discussion
Both vessels are modelled and tested in CFD using speed variations 5-10 knot, the variation were taken with consideration most of fishing vessels are operating between 5-10 knots.

| Speed (kn) | Resistance (kN) |
|-----------|-----------------|
|           | Flat Plate      | Conventional   |
| 5         | 11.62           | 9.30           |
| 6         | 16.82           | 13.84          |
| 7         | 23.23           | 19.76          |
| 8         | 31.39           | 28.02          |
| 9         | 40.62           | 38.70          |
| 10        | 54.53           | 49.96          |

The results of CFD resistance simulation can be shown by Table 6. It can be concluded that the resistance of Flat Plate is higher compared to conventional streamline vessel.

![Figure 10 CFD Resistance Comparison Flat Plate vs Conventional](image)

Beside resistance, this paper also compares pitch motion for both vessels where the results can be shown by Table 7.

| Speed (kn) | Motion Ry1 (pitch) |
|-----------|--------------------|
|           | Flat Plate         | Conventional     |
| 5         | 0.23               | -0.08            |
| 6         | 0.34               | -0.12            |
| 7         | 0.47               | -0.17            |
| 8         | 0.63               | -0.23            |
| 9         | 0.83               | -0.31            |
| 10        | 1.13               | -0.41            |
The value of pitch motion of Flat plate during resistance test in calm water shows positive value about 1.13 degree. This value represents that the flat plate is experiencing trim by bow around 0.3m during calm water resistance test. In contrary, the conventional streamline vessel shows negative value which shows that the conventional vessel is experiencing trim by stern.

![Figure 11 Pitch Motion Comparison](image)

Figure 11 confirmed there is a different behaviour from both vessel during the simulation resistance test, the left figure shows the flat plate stern is higher than the bow while the right figure shows that the bow is higher compared to stern. The stern draft of flat plate is higher compared to fore draft which contribute more resistance value compared to the conventional vessel.

In order to confirm the behaviour of both vessel, a towing tank experiment is required using the same procedure used in this paper. The towing tank experiment will confirm the resistance value and the pitch for 5-10 knots speed.

4. Conclusion
Based on the results and discussion, it can be concluded that the resistance of flat plate is higher based on the CFD results compared to conventional streamlined vessel for equal displacement Cb, draft and breadth. The other phenomena found from the CFD simulation is that the flat plate ship is experiencing trim by bow during test which this phenomena is not found in the conventional streamline vessel. In order to provide more solid evidence regarding the resistance and behaviour, a model test is required in a towing tank.

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References
[1] detik edu, “Mengenal Kapal Pelat Datar Buatan Teknik Perkapalan UI,” Aug. 24, 2021. [Online]. Available: https://www.detik.com/edu/perguruan-tinggi/d-5693516/mengenal-kapel-pelat-datar-buatan-teknik-perkapalan-ui
[2] Harwanto Bimo Pratomo, “Resmi diluncurkan, ini keunggulan kapal pelat datar inovasi anak bangsa,” merdeka.com, Jakarta, Sep. 04, 2018. [Online]. Available: https://www.merdeka.com/uan/resmi-diluncurkan-ini-keunggulan-kapal-pelat-datar-inovasi-anak-bangsa.html
[3] A Ziyadi, “Kapal Pelat Datar, Kapal Nelayan Yang Bisa Jadi Kapal Perang,” militermiliter.com, Jakarta, Jan. 16, 2017. [Online]. Available: https://militermeter.com/kapel-pelat-datar-kapel-nelayan-yang-bisa-jadi-kapel-perang/
[4] M. A. Budiyanto and H. T. Wibowo, “Perbandingan Nilai Hambatan Kapal antara Hasil Simulasi dengan Eksperimen pada Kapal Pelat Datar Semi-Trimaran,” in Seminar Nasional Tahunan Teknik Mesin XVI, Surabaya, Jun. 2017, vol. XVI, p. 4. [Online]. Available: http://prosiding.bkstm.org/prosiding/2017/KE-33.pdf
[5] N. Afriansyah, “Studi Desain Analisa Perbandingan Performance Kapal Perintis 750 DWT dengan Variasi Hull Menggunakan Pelat Datar,” vol. 6, no. 1, p. 8, 2018.

[6] M. A. Budiyanto and H. T. Wibowo, “Perbandingan Nilai Hambatan Kapal antara Hasil Simulasi dengan Eksperimen pada Kapal Pelat Datar Semi-Trimaran,” p. 4, 2017.

[7] F. H. Todd, “Viscous Resistance of Ships,” in Advances in Hydroscience, vol. 3, Elsevier, 1966, pp. 1–62. doi: 10.1016/B978-0-12-021803-5.50007-4.

[8] V. Bertram, “Resistance and Propulsion,” in Practical Ship Hydrodynamics, Elsevier, 2012, pp. 73–141. doi: 10.1016/B978-0-08-097150-6.10003-X.

[9] V. Bertram, “Introduction,” in Practical Ship Hydrodynamics, Elsevier, 2012, pp. 1–39. doi: 10.1016/B978-0-08-097150-6.10001-6.

[10] K. Niklas and H. Pruszko, “Full-scale CFD simulations for the determination of ship resistance as a rational, alternative method to towing tank experiments,” Ocean Engineering, vol. 190, p. 106435, Oct. 2019, doi: 10.1016/j.oceaneng.2019.106435.

[11] A.-M. Chiroșcă and L. Rusu, “Comparison between Model Test and Three CFD Studies for a Benchmark Container Ship,” JMSE, vol. 9, no. 1, p. 62, Jan. 2021, doi: 10.3390/jmse9010062.

[12] T. Perez and M. Blanke, “Simulation of Ship Motion in Seaway,” p. 14.

[13] D. Feng, B. Ye, Z. Zhang, and X. Wang, “Numerical Simulation of the Ship Resistance of KCS in Different Water Depths for Model-Scale and Full-Scale,” JMSE, vol. 8, no. 10, p. 745, Sep. 2020, doi: 10.3390/jmse8100745.

[14] ITTC, “ITTC – Recommended Procedures and Guidelines: Practical Guidelines for Ship Resistance CFD.” ITTC, 2014. [Online]. Available: https://ittc.info/media/4198/75-03-02-04.pdf

[15] G. R. Liu and S. S. Quek, “Modeling Techniques,” in The Finite Element Method, Elsevier, 2014, pp. 301–345. doi: 10.1016/B978-0-08-098356-1.00011-4.