Effect of Different Stern Flap Position and Size as an Energy Saving Device (ESD) for Increasing Fishing Boat Speed

S Klara¹, F Mahmuddin¹*, S Hariyanto¹, G Sitepu¹, and A A Aman¹

¹Marine Engineering Department, Faculty of Engineering, Hasanuddin University

*Email: f.mahmuddin@gmail.com

Abstract. One of the most issues on a boat for using energy is resistance. Therefore some energy is needed to be able to overcome the boat resistance. The total resistance depends on the speed of the boat. By reducing the resistance, it will affect the energy usage on the boat. One way to reduce the boat resistance is by installing a stern flap to the stern. Stern flap is a new addition on the stern appendage. Previous studies, the stern flap was able to reduce the resistance. The reduction of resistance occurred on boats can reduce fuel consumption, so it can be one of the innovations in combating the energy crisis. This study used an experimental method that analyzes the position and size of the stern flap, where each position and size of the flap were tested at the same load. From the results and analysis, it shows that the changing position of the stern flap on the surface of the water will increase the boat speed by 4.62% and the changing size of the stern flap size to 85 x 80 cm will increase the speed of the boat by 3.82%.

1. Introduction
There is a close relationship between humans and energy because energy can support human activities anytime and anywhere. It has been occurring since the industrial revolution when entering the 20th century. It is the greatest period of increasing energy usage in which various energies are produced and consumed, one of which is petroleum energy.

Increased human activities can reduce petroleum reserves. Reducing oil reserves requires energy savings to be done immediately. The society must think about how to develop energy-saving solutions, including in fishing-related activities. As we have known, fishing boats sail at the sea where it got drag force, which we called boat resistance. The reduction of boat resistance will also reduce fuel energy consumption. An optimization solution that needs to be done is to design a tool to reduce the resistance of the boat.

One of the most influential components in using energy from a boat is the propulsion system [1]. As we know, a boat is a complex and complicated object, because it can move at certain speeds both above and below the water surface. This incurs drag force or resistance in the water. The resistance effect depends on boat speed. By reducing the resistance experienced by the boat by installing a stern flap to the stern, it will affect all energy usage. Therefore, this study examines the efficiency of stern flap with different shapes and positions on a fishing boat to produce an optimum energy saving device (ESD).
2. Literature Review
The stern flap configuration on the boat is usually evaluated based on annual fuel consumption when compared to the supporting hull structures on the stern gate and without flap. The effect on main engine driving power is determined by the generator loads, etc., which are not considered in the present study. The engine’s exhaust gases can be calculated from the exhaust gases report at specific power levels.

2.1. Stern Flap
Stern flap is one of the additional appendage enhancements installed at the stern [2]. The hull interaction with the flap occurs at the trim condition, which reduces the propulsion resistance and increases the boat speed. The most important stern flap parameters are the length of the chord (L), the angle of the flap (a), and the flap span along the ship transom. Various stern flap studies found that it has an effect on boat performance. Stern flap specification depends on the boat dimension and stern shapes [3].

![Figure 1. An example stern flap](image)

The stern flap causes the lift force on the transom and changes the pressure distribution on the stern. On the stern flap, hull planning affects the trim in the 4.0 to 5.0 degrees. Where the displacement of the hull stern flap results in the trim reduction in the 0.1 to 0.3 degrees, this does not have a significant effect on reducing boat resistance. The basic advantage of adding the stern flaps is to make flow separation around the propeller. It provides drag force reduction on the stern and changes wave resistance from around the boat.

Other advantages of adding a stern flap are reducing resistance at a powering condition, increasing maximum speed, and changing the wave system in the transom area. The stern flap causes the hull flow to be decreased where the stern flap length is increased. Decreased flow velocity will increase pressure under the hull which causes a reduction in drag shape. The hydrostatic performance advantage of stern flaps is due to flow changes around the stern [5].

2.2. Hydrodynamic Effects of Stern Flaps
a. Stern Flow Change
Stern flaps reduce flow velocity and increase dynamic hull pressure. Increased pressure area causes greater lift force which produces a positive effect on boat movement. Stern flaps also increase the trailing edge outflow speed as compared to the transom area without flaps. This increased speed will reduce flow separation speed and make new flow separation well and reduce viscous pressure.

b. Wave System Transformation
Flow transfer around the stern area without stern flap causes energy loss due to eddy-making, turbulence, and white water condition. At the same time, stern flap in a flow area reduces the height, slope, and wave breaking. The stern flap also can reduce the wave height in the wave system near or far from the stern areas.
c. Lift and Drag Force
Stern flaps can produce lift and drag at all speeds and conditions. The advantage is the interaction with the hull and propeller so that it can reduce boat resistance. Lift and drag forces increase even greater as the chord length, span, and angle increase.

2.3. Boat Resistance
The speed caused by boat resistance is the fluid force acting in the opposite direction to the boat motion. The resistance will be the same as the fluid force component, which works parallel to the axis boat motion [6]. The boat must be designed as efficiently as possible with the minimum possible external force. So, boat resistance and boat propulsion have a very close relation.

The boat resistance is applied to find the boat thrust force so that the boat can move at the planning service speed. Meanwhile, the boat propulsion provides thrust force and the interaction between the boat motions against the fluid flow.

The boat resistance is generally divided into two components, namely:
1. Skin friction resistance given by Reynolds' number.
2. Residuary resistance due to waves given by Froude number.

While boats are moving forward with a certain speed, it will get drag force from fluid on the water. The drag force is caused by the fluid force, which in this case causes significant obstacles in boat motion. The power needed to overcome boat resistance for attaining a particular speed is determined by Eq. 1.

\[ P_E = RT \cdot V \]  
where,
\( P_E \) : effective Power (W)
\( RT \) : boat resistance (N)
\( V \) : boat velocity (knot)

In the boat resistance curve, the hull moves above and below the water surface mainly caused by fluid viscosity.

2.4. Froude Number and Reynolds Number
Froude number is a dimensionless number that is used to measure the resistance of an object moving through the water, and compare objects of different sizes. The Froud number is determined using Eq. 2.

\[ F_N = \frac{V}{\sqrt{g \cdot l}} \]  

Figure 2. Boat wave pattern without and with stern flaps
where,

\[ F_n : \text{Froude number} \]
\[ V : \text{boat velocity (m/s)} \]
\[ L : \text{boat length (m)} \]

In fluid mechanics, the Reynolds number is the ratio between the inertia force and viscous force which quantifies the relationship of the two forces with a certain flow condition. This number is used to identify different types of flow, for example, laminar and turbulent. Reynolds number is one of the most important dimensionless numbers in fluid mechanics and used to provide criteria for determining dynamic similitude. If two flow patterns are geometrically similar, perhaps different fluids and flow rates have the relevant value of dimensionless numbers, both are called dynamic similarities.

3. Research Methodology

3.1. Research Location

This research was conducted at the Bili-Bili Dam, Gowa Regency by using a boat named RV. SBL01.

3.2. Research Data

➢ Main dimension of RV. SBL01 boat:

| Dimension | Value (m) |
|-----------|-----------|
| LBP       | 7.73      |
| LWL       | 7.20      |
| LoA       | 7.93      |
| B         | 1.37      |
| H         | 0.60      |
| T         | 0.17      |

![Figure 3. RV. SBL01 boat](image)

➢ Stern flap size

In this study, we use two stern flap which are 85 x 80 cm and 55 x 80 cm sizes
In this study, two stern flap positions are used at above the surface of the water area and below the surface of the water area.

- **Main Engine**
  The main engine specifications of RV. SBL01 are as follows:
  - Engine Brand : Jiang Dong
  - Engine Type : 4 stroke
  - Engine Speed : 3600 rpm
  - Torque : 29.3 N.m
  - Engine Power : 15 Hp
  - BB tank capacity : 6.5 Litre
  - SFOC : 260 gr/Hp/hour
  - Quantities : 2
  - Tank Volume : 0.65 m$^3$
The research variables of this study are boat speed, position, and size of the stern flap. Collection of speed data using GPS (Global Positioning System). In this test, the boat operates for 10 minutes for each data measurement.

4. Results and Discussion

In this study, two ship conditions will be tested, namely no load and with load Conditions. The load of 15kg is placed at the stern of the boat. In addition, these conditions were tested on boats without flaps and with flaps of 85 x 80 cm and 55 x 80 cm sizes as shown in Fig. 4. From the research results obtained as follows;

4.1. Boat Testing Without Stern Flap

In this research, several variations of engine throttle are performed, namely 25%, 50%, 75%, and 100%, which are the percentages of each engine condition.

In this test, the boat without the load on the stern is in even keel condition. Where the boat initially experienced trim on the stern of -0.1 degrees and -0.4 degrees position when the boat is with the load.
Table 2. Boat Speeds without stern flap against without loading and with loading conditions

| Engine Throttle Variations (%) | Velocity (Knot) |
|-------------------------------|-----------------|
|                               | No Load | With Loading |
| 25                            | 6.7     | 6.8          |
| 50                            | 8.8     | 8.6          |
| 75                            | 10.4    | 10.6         |
| 100                           | 13.1    | 13           |

The results of this test shows that the no loading condition get 13.1 knots maximum speed, and each percentage of engine throttle variants will have some trim angle differences. When the engine throttle is increased to 100%, the stern is trimming into -1.2 degrees. On the other hand, the loading condition testing results get of 13 knots maximum speed and each percentage of engine throttle will have some trim angle differences. When the engine throttle is increased to 100%, the stern is trimming into -2.1 degrees.

4.2. Boat Testing With Stern Flap
In this study, the position of the stern flap is on the surface and below of the water both 85 x 80 cm and 55 x 80 cm sized also made the engine throttle division into 4 parts as in the test without flap, which is 25%, 50%, 75%, and 100% under loading and no loading conditions.

4.2.1. Water level condition testing
This test was conducted by positioning the stern flap parallel on the surface of the water as shown in Fig. 8.

Figure 8. Stern flap placed on the Water Surface
Table 3. Boat Speed with stern flap on water surface without no loading and loading conditions

| Engine Throttle Variations (%) | Boat Velocity (Knot) | 85x80 cm | 55x80 cm |
|-------------------------------|----------------------|----------|----------|
|                               | No Load | With Load | No Load | With Load |
| 25                            | 6.6     | 6.5       | 6.7     | 6.7       |
| 50                            | 7.9     | 8.4       | 8.6     | 7.9       |
| 75                            | 10.2    | 10.5      | 10.4    | 10.5      |
| 100                           | 13.4    | 13.6      | 13.4    | 13.3      |

The boat speed using 85 X 80 cm stern flap size without loading conditions shows that the boat gets 13.4 knots maximum speed and each percentage of engine throttle will have trim angle differences. When the engine throttle is increased to 100%, the stern is trimming into - 2.5 degrees. While the 55 X 80 cm flap stern size gets 13.6 knots maximum speed. When the engine throttle is increased to 100% too, the stern is trimming into -2.4 degrees.

While the boat is using 15 kg load at the stern, it gets trimming in -0.3 degrees at the stern. The maximum speed of the boat using 85 X 80 cm flap stern size is 13.6 knots, and each percentage of engine throttles will have some difference trim angle. When the engine throttle is increased to 100%, the stern is trimming into -2.4 degrees. For the 55 X 80 cm flap stern size gets 13.3 knots maximum speed, and each percentage of engine throttles will have some difference trim angle. When the engine throttle is at 75%, the trimming result is -1.7 degrees and when increased to 100%, the stern trimming is -2.1 degrees.

4.2.2. Underwater Surface Condition Testing
This test is done by positioning the stern flap below the surface of the water.

Figure 9. Stern Flap Size below the water surface

Table 4. Boat Speed with Stern Flap below the water surface without loading and with loading

| Engine Throttle Variations (%) | Boat Velocity (Knot) | 85x80 cm | 55x80 cm |
|-------------------------------|----------------------|----------|----------|
|                               | No Load | With Load | No Load | With Load |
| 25                            | 6.7     | 6.5       | 6.8     | 6.8       |
| 50                            | 8.9     | 8.5       | 8.1     | 8.3       |
| 75                            | 10.6    | 11.4      | 10.4    | 9.8       |
| 100                           | 13.1    | 13.5      | 13.3    | 13.2      |
Boat Speed Using 85 x 80 cm flap Stern without loading under water Surface, shows that the boat has 13.1 knots maximum speed, and each engine throttle percentage will have some trim angle differences. When the engine throttle is increased to 100%, the stern is trimming into -2.4 degrees. At the same time, the stern flap 55 X 80 cm has 13.3 knots maximum speed, and when the engine throttle is increased to 100%, the stern is trimming into -3 degrees.

In the boat testing using 15 kg load at the stern, initially, it gets stern trimming -0.3 degrees. The boat speed which used 85 X 80 cm flap stern size has 13.5 knots maximum speed. When the engine throttle is increased to 100%, the stern is trimming into -1.8 degrees. For the 55 X 80 cm flap stern size have 13.2 knots maximum speed, and each percentage of engine throttle will have some trim angle differences. When the engine throttle is increased to 100%, the stern is trimming into -2 degrees.

4.3. Discussion
From the test results, the different sizes and positions of the stern flap were placed on the stern of the boat can affect the boat speed when engine power testing is varied based on the engine throttle between loading and without loading condition. This can be explained as follows;

4.3.1. Effect of Stern Flap Size and Position due to Boat Speed without Loading
Figure 10 shows that the flap 85 x 80 cm and 55 x 80 cm size between on the water surface and below water surface get the same 13.4 knots speed and compared to without using the flap only get 13.1 knots speed. This shows that using flap addition on the stern will affect the increasing boat speed due to boat resistance reduction.

| Table 5. The Effect of stern flap size and position due to boat speed without loading |
|----------------------------------|---|---|---|---|---|
| Flap size                        | 25 | 50 | 75 | 100 |
| Without flap                    | 6.7 | 8.8 | 10.4 | 13.1 |
| Flap 55x80 cm at water surface  | 6.7 | 8.6 | 10.4 | 13.4 |
| Flap 55x80 cm at below water surface | 6.8 | 8.1 | 10.4 | 13.3 |
| Flap 85x80 cm at water surface  | 6.6 | 7.9 | 10.2 | 13.4 |
| Flap 85x80 cm at below water surface | 6.7 | 8.9 | 10.6 | 13.1 |

Figure 10. Effect of stern flap size and position due to boat speed without Loading
4.3.2. The Effect of Stern Flap Size and Position due to Boat Speed with Loading

From the graph in Fig. 11, it shows that flap 85 x 80 cm size in the water surface position has over 13.6 knots compared to the flap 55 x 80 cm size and also without using the flap have 13.3 knots and 13 knots. This shows that the change in size and position of the flap will affect the increasing boat speed due to boat resistance reduction.

| Flap size                          | Without flap (Knot) |
|------------------------------------|---------------------|
|                                    | 25      | 50      | 75      | 100     |
| Without flap                       | 6.8     | 8.6     | 10.6    | 13.0    |
| Flap 55x80 cm at water surface     | 6.7     | 7.9     | 10.5    | 13.3    |
| Flap 55x80 cm at below water surface | 6.8   | 8.3     | 9.8     | 13.2    |
| Flap 85x80 cm at water surface     | 6.5     | 8.4     | 10.5    | 13.6    |
| Flap 85x80 cm at below water surface | 6.5 | 8.5     | 11.4    | 13.5    |

5. Conclusions

Based on the results, it can be concluded that the boat speed due to the size and position of the stern flap on the water surface and below the water surface, are:
- Changing the position of the stern flap on the surface of the water will increase the speed of the boat into 4.62%.
- Changing the size of the stern flap 85 X 80 cm will increase the speed of the boat also into 3.82%

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