An Improvement for the Design of the Small Fiberglass Seaweed Farmers Boat to Minimize the Sinkable Risk

W Mustafa1*, S Asri1, M R Firmansyah1, F Fachruddin1, and G Apelaby1

1Department of Naval Architecture Engineering Faculty, Hasanuddin University, Makassar, Indonesia

*E-mail: wahyuddin.mustafa@unhas.ac.id

Abstract. The boat plays significant role in supporting the household business scale for the seaweed farmers. Their current boat are made from fiberglass reinforced plastic (FRP) which is lighter then the wooden boat. However, based on the field survey in the seaweed farmers boats in the area of Pattontongan village, Jeneponto regency, their boat is susceptible for sinking if any leak is occur on the boat body since they are not designed with the reserved buoyancy system. Geometry and the reserved buoyancy of their boat become the serious issues. Hence, an improved design for their boat is need to be developed with the criteria of the boat capacity and safety. This paper discusses two of the improved design of the boats which are ND1 (design 1) and ND2 (design 2). The result shows an improved design with the additional of the boat reserved buoyancy while considering the boat capacity. The parameter of the boat design is the relationship between the boat reserved buoyancy volume and the boat weight which is called anti sinking ratio. The anti sinking ratio for ND1 with the boat length 6 meters, width 0.85 meter, and height 0.5 meter is ≥ 1. The ratio is obtained in the condition of the boat reserved buoyancy of 0.066m³ and the boat carrying capacity of 0.969m³. Meanwhile, the anti sinking ratio for ND2 with the boat length of 4.2 meters, width 1 meter and height 0.5 meter is ≥ 1 in the condition of the boat reserved buoyancy of 0.055m³ and the boat carrying capacity of 0.936m³.

1. Introduction
Small boats are plays significant role in a seaweed cultivation process. The use of the boats are mainly for spreading the seaweed seed and during harvesting time. The safety of the boats are important since its frequently being used during the cultivation process. The material for the boats are from wooden and FRP. The latter is being mostly used compared to the wooden boat since it is lighter and simpler in maintenance.

Geometry of both the wooden and FRP boats is comparatively the same. The shape of the boats are log like. The proportion of the boat length and width is big while the proportion of the boat width and height is small. Hence, the boat stability is not good. Outriggers on the left and right of the boat are required to maintain the boat stability. The distance of the outriggers from the main body of the boat are 1 meter each. The current seaweed farmer’s wooden boat and FRP boat in the area of Pattontongan, Jeneponto regency can be seen in Figure 1.

Based on the visual observation and interviews, the current seaweed farmers boats are susceptible for sinking if any leak is occur on the boat body since they are not designed with the reserved buoyancy system. An experiment of sinking one boat have been conducted in order to prove the boat susceptibility (Figure 2).
Besides the lacking of the boat reserved buoyancy, the geometry of the current boat especially on the boat stem shape is raise another problem as well. The angle of the stem from the base line is around 45° and it’s restricted the movement of the farmers. The stem angle have been complained by some seaweed farmers since the success during the seaweed seed spreading and seaweed harvesting are depending on this stem angle.

![Figure 1. The wooden and FRP boat which have been used for seaweed cultivation in the area of Pattontongan, Jeneponto regency](image)

![Figure 2. Sinking the boat test to see the boat susceptibility in the area of Pattontongan, Jeneponto regency](image)

Since the geometry and the buoyancy of the current boat are being the main problems of the seaweed farmers, their boat design must be improved by considering their safety and working characteristics.

2. Review of the boat
Defining geometry of dimension and shape of any physical object is the first step before any production or manufacturing of the object begin. Ship and boat are one of the physical object to produce by mankind. The successful planning and production of the ship and boat is depending on the prior description of their geometry [1, 2]. However, the ship design is not only about geometry. The ability of the ship to operate safely in their environment is depending on the many ship characteristics and criteria such as stability, buoyancy, resistance, maneuvering and the ship structures itself. These ship characteristics cannot be seen directly merely from its geometry but instead it needs to be analyzed.

Currently, some research in the naval architectures are focusing on the development of practical engineering method for predicting the ship characteristics. Each analysis method is based on the ship geometrical foundation as each method requires ship geometrical representation as their input. The analysis can be conducted if the respective ship geometry have been determined [2-6]. Ship geometry can be described as ship particulars and it refers to the ship description of dimension, volume and other ship capacity such as Length Overall (LOA), Waterline Length (LWL), Length Between Perpendiculars (LBP or LPP), Beam (B), Draft (D), Displacement, Tonnage, Form coefficients [1, 2, 4-6].

Three of the ship analysis which is based on the ship geometry can be conducted on the ship weight analysis, ship hydrostatic analysis and ship hydrodynamic analysis. The ship weight analysis is one of the important component of the ship design which connect ship weight and capacity. The analysis requires calculation on the length, area, volume, center of gravity for surface and space as well as
requires knowledge on the weight units such as weight/length, weight/area and weight/volume of the construction material [2, 4].

The hydrostatic analysis is the most common ship geometrical evaluation being used. It evaluates forces and moments as the result of the ship static balance as well as static fluid pressure variable which working on the ship surface and on the free surface area in the ship tank [2, 4, 5, 6]. While hydrodynamic analysis predicting forces, movement and structural load as the result of the ship movement on the water, the water flow around the ship including the effect of the sea wave. Though the hydrodynamic analysis is complex but simplicity and prediction of the fluid flow as well as the ship geometry can be applied [2, 4, 7].

3. Research Method
Methodology for solving the fiberglass boat geometry and reserve buoyancy problems can be divided into several stages which are measuring and collecting the “base/sample boats” dimension, determining the “base boat” particulars and then determining the improved boat design particular. Based on the latter information, the correlation between the boat capsizing ratio and the boat carrying capacity is determined.

4. Result and Discussion
The improved boat design was developed based on the three boat samples which being used by the seaweed farmers (“which become the base boats”). Based on the current boat direct measurement, weight and hydrostatic analysis, the characteristic geometry or the “base boats” particular are determined. The base boat lines plan and the boat particulars can be seen in Figure 3 and Table 1.

| Designation                        | Symbol | Unit | BB1   | BB2   | BB3   |
|-----------------------------------|--------|------|-------|-------|-------|
| Length Overall                    | LOA    | m    | 6.00  | 6.50  | 7.30  |
| Length Between Perpendiculars     | LBP    | m    | 5.66  | 6.13  | 6.54  |
| Breadth /Beam                     | B      | m    | 0.70  | 0.65  | 0.65  |
| Depth                             | D      | m    | 0.60  | 0.60  | 0.64  |
| Draft                             | T      | m    | 0.41  | 0.50  | 0.50  |
| Block coefficient                 | C_B    |      | 0.52  | 0.56  | 0.52  |
| Midship section coefficient       | C_M    |      | 0.81  | 0.86  | 0.80  |
| Water plane coefficient           | C_WP   |      | 0.71  | 0.75  | 0.76  |
| Prismatic coefficient             | C_P    |      | 0.64  | 0.66  | 0.65  |
| Volume of displacement            | V      | m³   | 0.73  | 0.86  | 0.97  |
| Displacement                      | Δ      | kg   | 747.80| 881.30| 998.10|

Considering the base boat particulars as well as the farmer’s needs, the improved boat designs are developed based on the displacement volume constant value of 0.73 m³. The value is selected in order to keep the boat weight of 80 kgs or less so that it can be carried by at least two seaweed farmers.

The result of the boat weight and hydrostatic analysis in order to obtain the boat particulars as well as the boat lines plan can be seen in Figure 4 and Table 2.
Figure 3. The lines plans of the three base boats.

Table 2. The main particulars of the two improved boat design

| Designation                     | Symbol | Unit | Design 1 (ND₁) | Design 2 (ND₂) |
|---------------------------------|--------|------|----------------|----------------|
| Length Overall                  | LOA    | m    | 6.00           | 4.20           |
| Length Between Perpendiculars   | LBP    | m    | 5.60           | 4.00           |
| Breadth /Beam                   | B      | m    | 0.85           | 1.00           |
| Depth                           | D      | m    | 0.50           | 0.50           |
| Draft                           | T      | m    | 0.35           | 0.35           |
| Block coefficient               | C_b    |      | 0.49           | 0.52           |
| Midship section coefficient     | C_M    |      | 0.80           | 0.88           |
| Water plane coefficient         | C_wp   |      | 0.66           | 0.65           |
| Prismatic coefficient           | C_p    |      | 0.62           | 0.59           |
| Volume of displacement          | V      | m³   | 0.73           | 0.73           |
| Designation | Symbol | Unit | Design 1 (ND₁) | Design 2 (ND₂) |
|-------------|--------|------|----------------|----------------|
| Displacement | Δ      | kg   | 748.10         | 748.5          |
| L/B         |        |      | 7.22           | 4.07           |
| B/T         |        |      | 2.24           | 2.84           |
| L/D         |        |      | 12.00          | 8.40           |

![Design 1 (ND₁)](image1)

![Design 2 (ND₂)](image2)

**Figure 4.** The lines plans of the two improved boat designs

The basic difference of the improved boat design to compare with the base boats is in the midship section shape and in the angle of the boat stem. In the improved boat designs, the chine shape of the boat have been applied to get the wider boat base. The purpose of the application is to ease the farmers to dock the boat on the beach. The angle of the boat stem is to be made steep as well in order to minimize the accident risk to the farmers while working.

The other problem to be solved in the improved boat design is to minimize the risk of the boat to be sinking in case of any leak in the boat. Hence, the improved design must be added with the boat reserved buoyancy while keep considering the boat capacity. The improved boat design must have the anti sinking ratio more than 1. The anti sinking ratio is the relationship between the boat reserved buoyancy volume and the boat hull weight. Figure 5 shows the arrangement of the empty tanks as the source of the boat reserved buoyancy.

Based on the general arrangement (GA) drawing as can be seen in Figure 5, the value of the boat reserved buoyancy and the boat weight are being simulated and the result of the analysis can be seen in Table 3 and Figure 6.
Figure 5. The general arrangement of the both improved boat design

Table 3. Anti sinking ratio of the improved boat design

| No | Length of tank (m) | Reserved Buoyancy Volume (m³) | Boat Hull Weight (ton) | Anti Sinking Ratio | Cargo Hold Volume (m³) |
|----|--------------------|--------------------------------|------------------------|--------------------|-----------------------|
|    | AP | FP | AP | FP | Total |                                |                        |                     |                     |
|    | 1  | 2  | 3  | 4  | 5     | 6=4+5                         | 7                     | 8=6/7               | 9                   |
| 1  | 0.65 | 0.65 | 0.031 | 0.017 | 0.048 | 0.065 | 0.742 | 0.987 |
| 2  | 0.70 | 0.70 | 0.036 | 0.021 | 0.057 | 0.065 | 0.881 | 0.978 |
| 3  | 0.75 | 0.75 | 0.041 | 0.025 | 0.066 | 0.065 | 1.021 | 0.969 |
| 4  | 0.80 | 0.80 | 0.047 | 0.030 | 0.077 | 0.065 | 1.191 | 0.958 |
| 5  | 0.85 | 0.85 | 0.053 | 0.035 | 0.088 | 0.065 | 1.361 | 0.947 |
| 6  | 0.90 | 0.90 | 0.060 | 0.040 | 0.100 | 0.065 | 1.546 | 0.935 |
| 7  | 0.95 | 0.95 | 0.067 | 0.046 | 0.113 | 0.065 | 1.748 | 0.922 |
| 8  | 1.00 | 1.00 | 0.075 | 0.052 | 0.127 | 0.065 | 1.964 | 0.908 |
| 9  | 1.05 | 1.05 | 0.082 | 0.058 | 0.140 | 0.065 | 2.165 | 0.895 |

Improved Design 2 (ND₂)

| No | Length of tank (m) | Reserved Buoyancy Volume (m³) | Boat Hull Weight (ton) | Anti Sinking Ratio | Cargo Hold Volume (m³) |
|----|--------------------|--------------------------------|------------------------|--------------------|-----------------------|
|    | AP | FP | AP | FP | Total |                                |                        |                     |                     |
| 1  | 0.45 | 0.45 | 0.019 | 0.015 | 0.034 | 0.052 | 0.65 | 0.957 |
| 2  | 0.50 | 0.50 | 0.024 | 0.020 | 0.044 | 0.052 | 0.84 | 0.947 |
| 3  | 0.55 | 0.55 | 0.030 | 0.025 | 0.055 | 0.052 | 1.05 | 0.936 |
| 4  | 0.60 | 0.60 | 0.037 | 0.031 | 0.068 | 0.052 | 1.30 | 0.923 |
| 5  | 0.65 | 0.65 | 0.044 | 0.038 | 0.082 | 0.052 | 1.57 | 0.909 |
| 6  | 0.70 | 0.70 | 0.053 | 0.045 | 0.098 | 0.052 | 1.87 | 0.893 |
| 7  | 0.75 | 0.75 | 0.062 | 0.053 | 0.115 | 0.052 | 2.20 | 0.876 |
| 8  | 0.80 | 0.80 | 0.072 | 0.062 | 0.134 | 0.052 | 2.56 | 0.857 |
| 9  | 0.85 | 0.85 | 0.083 | 0.072 | 0.155 | 0.052 | 2.96 | 0.836 |
Figure 6. The relationship between anti sinking ratio with the boat carrying capacity of both of the improved boat design.

The improve design 1 (ND$_1$) and The improve design 2 (ND$_2$)

Ratio number of ≥ 1 on Figure 6 means that in case of any leak on the boat and the seawater entering the boat up to the boat deck, the boat cannot be sinking into the seabed but instead the boat is still floating even in the upside down position. The value of the boat reserved buoyancy is influencing the boat carrying capacity (cargo hold capacity). If the value of the boat reserved buoyancy increase, then the boat carrying capacity will be decrease.

Based on both graphs in Figure 6, the improved design 2 (ND$_2$) seem to be more realistic to be applied as the length of the boat is smaller than ND$_1$ with almost the same capacity.

5. Conclusion

The result shows an improved design with the additional of the boat reserved buoyancy while considering the boat capacity. The parameter of the boat design is the relationship between the boat reserved buoyancy volume and the boat weight which is called anti sinking ratio. The anti sinking ratio for ND$_1$ with the boat length 6 meters, width 0.85 meter, and height 0.5 meter is ≥ 1. The ratio is obtained in the condition of the boat reserved buoyancy of 0.066 m$^3$ and the boat carrying capacity of 0.969 m$^3$. Meanwhile, the anti sinking ratio for ND$_2$ with the boat length of 4.2 meters, width 1 meter and height 0.5 meter is ≥ 1 in the condition of the boat reserved buoyancy of 0.055 m$^3$ and the boat carrying capacity of 0.936 m$^3$.

Acknowledgments

The authors would like to thanks the Faculty of Engineering, Universitas Hasanuddin for its research grant under scheme of Labo Base Education (LBE) research 2019 so as this research work can be done. The appreciation is given as well to the members of the seaweed farmers group in Pattontonga City for their help and cooperation during data collection and interviewing process in location.

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