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The application of solid boxes on small passenger speed-boat

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Abstract. The application of solid boxes to prevent the sinking of small boats had been executed by the authors with small tuna-long boats. This concept was continued to be applied on small passenger speed-boats to find the possibility of application of solid boxes. This is due to some restrictions of spaces inside small passenger boats. The purpose of application of solid boxes on board is to reduce the incoming water and to prevent the boat from sinking. The data of full-scale boats were collected and developed into Maxsurf software. A scale boat model was developed by this software in order to compute and analyze the boat parameters as well as to construct the real boat model. The boat model was arranged for the details of weight components and their centers. The incoming water was filled into the model and tested for its sinkage. The results showed that the boat was sink. Therefore for future work, other method should be considered on the model in order to prevent it from sinking.

1. Introduction

The transpotation of passengers in maritime countries is really required due to the existing geographical conditions and the need of people to move among the places. This mode of transport can be performed by small and medium size of passenger ships. For a short travel distance such as islands connection, the need of fast small passenger ships (speed boats) is significant. This is due to small input of passenger numbers and short travel time at sea. In fact, there are a lot of accidents at sea due to worst sea conditions. Those conditions end-up with the sinking of boats and lost of passengers at sea. This issue was solved by introducing a new innovation of designing an unsinkable passenger speed boat. The aim of this research is to prevent the boat from sinking and to safe passengers at sea.

This research was a development of previous research with small tuna long-boats executed by the authors [1, 2, 3]. In the previous works, the boats were provided with solid boxes in order to reduce the amount of incoming water on board. The results showed that the boats still afloat when filled with water. However, the application of solid boxes in small passenger boats was not practice. This is due to the greater spaces on board required for the passengers. In this research, the possibilities of application of solid boxes at certain places were determined. Futhermore the solid boxes were applied at small size of boat model. The research was started with an experimental work on unsinkable scale-model. To execute this work, the data were collected from the existing boats. Then, they were developed in Maxsurf software to perform the boat size, geometrical hull form and other boat paremeters. In addition, the developed data were applied to construct the model and to be tested in the tank. During the work, the parameters of model were defined to represent those of full-scale boat. The results obtained from the model were predicted for the real (full-scale) boat. It was found that the amount of solid boxes on board were not enough to prevent the boat from sinking. Other scenario will be considered to develop an additional material for future works.
2. Literature Review

2.1. Safety aspect on passenger transportation in archipelago regions
The need of passenger transport in archipelago regions is highly required. Passengers are looking for fast small boats to reach their travel in short time. In fact, there are many accidents occur during the travel, particularly in Moluccas waters as well as in other Indonesian waters [4]. The authors highlighted some reasons which cause the accidents on speed boats [2, 5] such as strong winds and waves, sea currents as well as human errors in operating the small passenger boats. In addition, other factors that may contribute to the accidents are overload cargo, low skill of boat operators, less safety and communication equipments, less stability quality and less control from the authority institutions. Some recommendations were suggested by the authors such as: stop the boat operation in worst sea conditions, evaluate the seaworthiness of boats and equipments. In addition, the author proposed a new innovation of unsinkable passenger boats.

2.2. Previous work with unsinkable small fishing boats
Previous work executed by the authors with small tuna long boats was to prevent them from sinking [1, 2, 3]. The output was contributed to the local boat builders and fishermen. The boats were made of material of Fibreglass Reinforced Plastic (FRP) and equipped with some solid boxes in order to reduce the incoming water on boat. In addition, the solid boxes were useful as reserve buoyancy when the boats were in capcized condition. The boats were redesigned, constructed and evaluated for sinkage condition. They were unsinkable (Figure 1). The output was implemented to the local boat builders and stakeholders by providing the training programme (Figure 2). The results have been used in many local boat yards in Moluccas.

\[ \Delta = W \]
\[ W = LWT + DWT \]

where:
\[ \Delta \] = weight displacement, \[ W_{total} \] = total ship weight;
\[ LWT \] = light ship weight, \[ DWT \] = dead weight

Weight displacement of ship (\( \Delta \)) may be computed as:
\[ \Delta = C_B \times L \times B \times T \times \rho \]  

where: 
- \( L \) = ship length 
- \( B \) = ship beam 
- \( T \) = ship draft 
- \( C_B \) = block coefficient 
- \( \rho \) = specific weight (=1.025 ton/m\(^3\) for sea water) 

Therefore, for a ship to be float at the draft \( T \), then \( W = \Delta \) 

For the case when a ship to be sink: 
\[ W_{\text{total}} > \Delta = C_B \times L \times B \times H \times \rho \]  

In this case, \( H \) = ship height and since \( LWT \) is constant then the additional weights are coming from additional \( DWT \) which is the incoming water on board. 

2.4. Inovation of unsinkable ship 

The last equation (4) shows us that there should be some materials provided on board in order to reduce the incoming water. These problems were executed by providing some light solid boxes (materials FRP) and injected the foam inside. This concept is explained as showed in Figure 3. 

![Figure 3. The composition of solid boxes on board](image)

In figure 3, the volume of the ship consists of the existing solid boxes, additional solid boxes and other additional material. The possible incoming water could fulfill the total of ship volume. Therefore, to reduce the volume for incoming water then the size of solid boxes should be greater. However, this is not practice to be applied for passenger boats. 

3. Methodology 

3.1. Boat data 

The data are required in computing the parameters and constructing the boat model. The data were collected in three spots in Ambon Island namely Kota Jawa, Tulehu and Hitu villages (Figure 4). 

![Figure 4. Boat data collecting](image)

To execute the model test, a scale factor \( \lambda = \text{length of full-scale boat/length of model} = 4 \) was determined. Then the data of full-scale boat and model are presented at Table 1. 

| No | Parameter Speed Boat | Symbol | Value | Unit |
|----|----------------------|--------|-------|------|
| 1  | Length Overall      | \( L_{OA} \) | 6.61  | 1.652 | m    |
| 2  | Length of Waterline | \( L_{WL} \) | 6.35  | 1.587 | m    |
| 3  | Beam                | \( B \)  | 1.40  | 0.350 | m    |
| 4  | Draft               | \( T \)  | 0.40  | 0.163 | m    |
| 5  | Height              | \( H \)  | 0.65  | 0.100 | m    |
| 6  | Speed               | \( V_s \) | 13.0  | -     | knot |
Other boat data were collected as follows:

- **Passenger numbers**: 15
- **Prime Mover**: outboard 25 to 40 HP
- **Autonomy**: 5 to 30 n.m
- **Passenger luggage**: 25 kg average
- **Equipments**: anchor, fuel tank
- **Fuel**: 20 to 50 l

### 3.2. Boat drawing and parameters

The drawings are required in order to develop the model and to compute the boat parameters. It was also used to determine the size of solid boxes. The drawings are lines plan (Figure 5) and general arrangement (Figure 6). The boat parameters of hydrostatics and weight are required in order to find the displacement (Figure 7). From the computation of hydrostatics, it was found the boat hull displacement of 977 kg while the total real hull weight is 974 kg with a difference of 0.3%.

#### Figure 5. Lines plan

#### Figure 6. General arrangement

#### Figure 7. Hydrostatic parameters

The light weight and dead weight of the boat are presented at Table 2. In addition, the weight of model was fixed due to the scale factor $\lambda = 4$.

| No | Item weight          | Unit | $\lambda = 4$ | $\lambda^3 = 64$ |
|----|----------------------|------|----------------|------------------|
| 1  | Hull                 | kg   | 974            | 15.22            |
| 2  | Outboard engine      | kg   | 81             | 1.27             |
| 3  | Fuel and tank        | kg   | 21             | 0.33             |
| 4  | Anchor               | kg   | 5.5            | 0.086            |
| 5  | Anchor rope          | kg   | 3              | 0.047            |
| 6  | Passenger and operator | kg | 1125         | 17.58            |
| 7  | Luggage              | kg   | 70             | 1.1              |
|    | Total                |      | 2280           | 35.633           |

### 3.3. Developing of boat model

The boat model was developed based on the full-scale data. The size was fitted due to the scale factor $\lambda$. Geometrical hull form of the model was formed based on the lines plan of the boat. The construction of model was executed in three stages. They were inner template, model template and boat model (Figures 8, 9). In addition, solid boxes, equipments and all testing procedures were...
performed during constructing the model. The model was built and tested at Laboratory of Ship Construction, Faculty of Engineering (Figure 10).

Figure 8. Construction of boat template

Figure 9. Construction of boat models and air boxes

Figure 10. Model testing at the tank

4. Results and Discussions

4.1. Volume of solid boxes
Solid boxes were computed based on the possibility that may be placed on board. The amounts of solid boxes were determined both for full-scale boat and model as showed in Table 3. In addition, the amounts of incoming water to fill all spaces were computed in this work.

Table 3. Volume of all kind of spaces on board

| No | Type of space                    | Position on board | Volume Model(cm$^3$) | Volume Boat (m$^3$) | Weight of incoming water Model (kg) | Weight of incoming water Boat (ton) |
|----|----------------------------------|-------------------|----------------------|---------------------|------------------------------------|------------------------------------|
| 1  | Empty boat                       | All               | 54900                | 3.514               | 54.900                             | 3.602                              |
| 2  | Solid box seats                  | Middle            | 13600                | 0.870               | 13.600                             | 0.087                              |
| 3  | Solid box bottom                 | Bottom            | 1600                 | 0.102               | 1.600                              | 0.010                              |
| 4  | Solid box bow                    | Bow               | 800                  | 0.051               | 0.800                              | 0.005                              |
| 5  | Solid box aft                    | All               | 1850                 | 1.118               | 1.850                              | 0.012                              |
| 6  | Passenger, equip. & luggage       | All               | 7650                 | 0.490               | 0.765                              | 0.005                              |
| 7  | Incoming water                   | All               | 29400                | 1.883               | 29.400                             | 1.930                              |

4.2. Results of the model test
The model was tested in the tank by filling the water on board. In this process, all passenger makets, equipments were fixed at their places. The water was filled up to a certain amount when boat model at sink condition. The amount of water required when the boat at sink condition was 21.02 kg based on the result of measurement. This is compared to that of theoretical computation which is 21.363 kg. The
result of measurement is presented in Table 4 and is showed in Figure 11. From the picture it is seen that when the water reach a certain amount then the boat model will sink and capcizes.

Table 4. Incoming water on board

| No | Item weight                  | Unit | Boat | Model |
|----|------------------------------|------|------|-------|
| 1  | Boat weight                  | kg   | 2280 | 35.633|
| 2  | Incoming water               | kg   | 1930 | 29.400|
| 3  | Total weight                 | kg   | 4210 | 65.033|
| 4  | Max displacement at boat height | kg | 3737 | 56.966|
| 5  | Max incoming water when boat sink | kg | 1457 | 21.363|
| 6  | Real measurement             | kg   |      | 21.020|

Figure 11. Test of model sinking

4.3. Discussion
From the results of model test it may be seen that the boat model will sink when the amout of 21.02 kg of water were filled into the boat. This amount of water was required to fulfill the total capacity of displacement at boat height. From the theoretical computation it was required 21.36 kg of water to sink the boat. However, at this condition the boat was unstable and ready to sink. Furthermore, when the boat was full of water it will easily capcized due to loss stability.

The amounts of solid boxed installed on board were not sufficient enough to prevent the incoming water on board. This is due to limitation of solid boxes to be installed on board. The numbers of solid boxes fixed at bottom, seats, fore and after parts with the total of 17850 cm³ were not enough. Therefore, there should be another consideration to prevent incoming water on board.

5. Conclusions and Future Works

5.1. Conclusion
After executing the boat model test at the tank, there were some points that may be resumed. They are concluded as follows:
1. The total amout of 21.02 kg water may sink the model or 1.47 ton of water may sink the full-scale boat
2. The total volume of 17850 cm³ solid boxes of model or 1.141 m³ solid boxes of full-scale boat could not prevent the model or boat from sinking
3. There should be additional materials provided on board to prevent the incoming water that may sink the model or boat.
4. There should be also good arrangement of materials that provide good stability of the model or boat.

5.2. Future works
Future works should be performed in order to prevent the boat from sinking. It is suggested to apply “expanded air boxes” which could be practice for the passenger boats.

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