Study comparative of stability performance between PVC fishing boat and wooden traditional fishing boat

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ABSTRACT: The use of PVC materials as an alternative material for fishing boat is being developed in Pekalongan, Central Java, Indonesia. Therefore, further analysis is needed to assist this development. In this paper, the analysis of ship stability of PVC fishing boat is investigated and be compared with wooden traditional fishing boat. The results of this analysis indicate that the PVC fishing boat has better stability which the PVC boat has GM values greater than traditional fishing boat. The GM values of traditional fishing boat is 3.988 m on normal load conditions, while the PVC fishing boat has a GM value of 5.828 m.

1. Introduction
In ancient era, the water transport is often used in Indonesian island is a raft. The used material is many bamboos which is arranged in such a way as to assemble a raft. This transportation is the beginning of the creation of modern ships. The raft is applied as a crossing tool between an island to other one or used by fisherman to catch a fish. In Taiwan, the rafts are mostly found, but using different materials. As a substitute for bamboo, PVC pipes are used to make rafts. With a ship length about 30-40 feet, the PVC boat is used to catching fish. The driving machine used is a diesel engine.

Actually, the fishing boat in Indonesia mostly use wood as raw materials. The wood used is not just any wood, but the kind of wood that has certain conditions, such as resistant to underwater environment, and has good properties of material strength. The wood used is usually old age and has a long size. Recently, the wood for boat material is decreasing and difficult to be obtained. In the long term, the logging for boat material can damage the environment.

In Indonesia on 2016, there is already fishing boat that use an alternative material instead of wood, one of which is Poly Vinyl Chloride (PVC). The fishing boat uses PVC material for hull part and expected to minimize the cost of manufacture and shorten the working time. The cost used to make a ship made of PVC ranges from IDR 800 million, while the fishing boat in general reach IDR 1.2 billion. The production time of the PVC fishing boat is also relatively faster about five months compared with the wooden boats production usually takes up to seven months. However, from the ship performance side, the stability of PVC fishing boat need to be assessed and compared with IMO regulation. In this research, the analysis of ship stability of PVC fishing boat is investigated and compared with wooden traditional fishing boat.
2. Literature review
PVC (Polyvinyl Chloride) was discovered accidentally by Henri Viktor Regnault in 1835 and Eugen Baumann in 1872. At the beginning of the 20th century, Russian chemist Ivan Ostromislensky and Fritz Klatte of the German chemical company Griesheim-Electron tried to use PVC as commercial products. But the difficulty of material pruning hinders their efforts. In 1926, Waldo Semon and the B.F Goodrich company developed the method of making PVC become truly plastic by adding some additives. As a result, PVC is more flexible and easier to process which then reaches global usage.

Polyvinyl chloride (PVC) is a pipe made of plastic and some other vinyl combinations. It is a third generation of thermoplastic polymer in terms of world usage, after polyethylene and polypropylene. Around the world more than 50% of PVC produced is used as a construction material. PVC is relatively cheap, durable, and easy to assemble. PVC can be made more elastic and flexible by adding plasticizer. The mandatory stability requirements of ships shall refer to the standards established by the local Indonesian Bureau of Classification or the Marine Authority such as International Maritime Organization (IMO). Thus the process of stability analysis carried out must be in accordance with IMO (International Maritime Organization) standards. Code A.749 (18) Ch 3 - design criteria applicable to all ships Section A.749 (18), Chapter 3.1.2.3: The area under the curve GZ at oscillation angle 0º- 30º ≥ 3.101 m.deg, area 0º- 40º (deg) ≥ 5.157 m.deg and area 30º- 40º ≥ 1,719 m.deg. Chapter 3.1.2.2: Maximum GZ value occurring at an angle of 30º-180º ≥ 0.2 m. Chapter 3.1.2.2: angle at the maximum GZ value ≥ 25 º. Chapter 3.1.2.4: Early GM at 0º ≥ 0.15 m [1]. For ship stability analysis, the principle dimension of wooden traditional fishing boat and PVC fishing boat can be seen in table 1.

| The wooden traditional fishing boat |
|-----------------------------------|
| 1 Length (LOA) | 15 m |
| 2 Breadth | 5.2 m |
| 3 Height | 1.8 m |
| 4 Draught | 1 m |
| 5 Tonnage | 17 GT |

| The PVC fishing boat |
|----------------------|
| 1 Length (LOA) | 18.3 m |
| 2 Breadth | 4.5 m |
| 3 Height | 0.75 m |
| 4 Draught | 0.75 m |
| 5 Tonnage | 17 GT |

3. Results and discussion
First, the wooden traditional fishing boat and PVC fishing boat is developed in 3D model for the stability calculation (figure 1) [2, 3]. The stability analysis calculated under various loading conditions. The loading conditions that are investigated such as: departure condition, condition at sea when catching fish, and arrive condition [4-6]. The stability performance of wooden traditional fishing
boat is obtained as in table 2 and figure 2. While the stability performance of PVC fishing boat can be seen in table 3 and figure 3.

![Figure 1. 3D Model of wooden traditional fishing boat and PVC fishing boat.](image)

**Table 2.** Stability analysis for the wooden traditional fishing boat.

| No | Criteria                      | IMO  | Units | Load Condition |
|----|-------------------------------|------|-------|----------------|
|    |                               |      |       | I          | II          | III         |
| 1  | Area 0 to 30                  | 3.151| m.deg | 26.817     | 23.600      | 21.655      |
| 2  | Area 0 to 40                  | 5.157| m.deg | 44.040     | 38.424      | 35.055      |
| 3  | Area 30 to 40                 | 1.719| m.deg | 17.222     | 14.824      | 13.400      |
| 4  | GZ on 30 and more             | 0.2  | m     | 1.952      | 1.650       | 1.460       |
| 5  | Max GZ angle                  | 25   | deg   | 50.9       | 49.1        | 49.1        |
| 6  | Initial GMt value             | 0.15 | m     | 3.988      | 3.510       | 3.221       |
| 7  | Initial GMt value for         | 0.35 | m     | 3.988      | 3.510       | 3.221       |
|    | ships ≥ 24 m                  |      |       |             |             |             |
| 8  | Initial GMt value for         | 0.15 | m     | 3.988      | 3.510       | 3.221       |
|    | ships ≥ 70 m                  |      |       |             |             |             |
|    | Status                        |      |       | Pass        | Pass        | Pass        |
Figure 2. Graph of GZ Values for the wooden traditional fishing boat

Table 3. Stability analysis for the PVC fishing boat.

| No | Criteria                     | IMO | Units  | Load Condition | I     | II    | III    |
|----|-------------------------------|-----|--------|----------------|-------|-------|--------|
| 1  | Area 0 to 30                  | 3.151 | m.deg  | 26.765         | 16.803 | 10.733 |
| 2  | Area 0 to 40                  | 5.157 | m.deg  | 38.567         | 22.839 | 14.524 |
| 3  | Area 30 to 40                 | 1.719 | m.deg  | 11.802         | 6.036  | 3.791  |
| 4  | GZ on 30 and more             | 0.2  | m      | 1.187          | 0.652  | 0.401  |
| 5  | Max GZ angle                  | 25   | deg    | 31.8           | 19.1   | 17.3   |
| 6  | Initial GMt value             | 0.15 | m      | 5.828          | 3.705  | 3.062  |
| 7  | Initial GMt value for ships ≥ 24 m | 0.35 | m      | 5.828          | 3.705  | 3.062  |
| 8  | Initial GMt value for ships ≥ 70 m | 0.15 | m      | 5.828          | 3.705  | 3.062  |

Status  | Pass     | Pass    | Pass    |

Figure 3. Graph of GZ Values for the PVC fishing boat.
The calculation of ship stability performed in this study analyzes the 3 conditions of each model that have been made, in accordance with IMO A.749 (18) Chapter 3.5. As for the 3 conditions are:

a. Condition I: Represents a ship condition before departing from port to fishing ground. Under these conditions, the vessel in a consumable charge state is empty.

b. Condition II: The ship is already on the fishing ground. In this condition, the ship has been given additional cargo ship (mackerel) 50%.

c. Condition III: The ship is still on the fishing ground. In this condition, the boatload (mackerel) is 100%.

Table 2 and table 3 show that the value of the area under the GZ curves at points 1, 2, and 3 for wooden traditional fishing boats and PVC fishing boats are still above the IMO standard. At the heel angle that assumed as down flooding point of the ship, that is between 0 - 30 degrees, 0 - 40 degrees and 30 - 40 degrees. Both of boats are still in the stable conditions because they have a large righting moment. While IMO standard on points 4 and 5 mentions that minimum distance and minimum angle at maximum GZ value should not less than 0.2 m and 25 degrees. From the calculations on all conditions stated that the GZ value for wooden traditional fishing boat and PVC fishing boat are still above the IMO standard.

IMO rule on point 6 states that the distance of metacenter gravity (MG) for minimum fishing boat is 0.35 m and the results show that MG values for wooden traditional fishing boats and PVC fishing boat under all conditions are above the standard set of requirements set by IMO. This condition can be declared stable because it has a positive MG value.

4. Conclusion

The GZ value of PVC fishing boat at condition I of 1.577 m; condition II of 1.266 m; the condition of III is 1.181 m which has fulfilled the criteria specified by IMO. The MG value of PVC fishing boat on condition I amounted to 3.624 m; condition II of 2.654 m; condition III of 2.700 m which already fulfill the criteria specified by IMO. While, The GZ value of wooden traditional fishing boat at condition I of 1.820 m; condition II of 1.573 m; condition III of 1.398 m where the value has also met the criteria specified by IMO. The MG value of wooden traditional fishing boat condition I is 3.617 m; condition II of 3.244 m; condition III equal to 2.981 m where the value already fulfill the criteria specified by IMO.

The model of PVC fishing boat has better the stability performance than wooden traditional fishing boats, because it has larger MG distance than the wooden traditional fishing boat model. The large MG value makes the ability to reverse the ship in its original position become better.

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