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Experimental study of a ship with the self-righting moment in extreme condition

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Abstract. Patrol vessel is an essential part of offshore security archipelago countries such as Indonesia. The main feature of patrol vessel is operating in rough waves during operation. Ship stability is one of the challenging aspects of patrol vessel because, in extreme conditions, the ship can capsize due to losing a self-righting moment. The present paper carried out a study of a patrol vessel with a self-righting moment in extreme conditions. The condition is a ship with rolling up to above 180^0. Thus, the ship can capsize because of losses of the self-righting moment in rough condition. An experimental study is carried out to model a ship with a rolling angle above 180^0. The principal dimension of ships Lpp, B, H, T, are 13.0 m, 4.2 m, 2.19 m and 1.15 m, respectively. The study was carried out with a physical model of ship 1:27.4. The model is made using 3D printing to maintain the hull integrity. In the present paper, only the full load condition was tested in the experiment condition. It was showed the ship design was proven to have a self-righting moment in the rolling angle above 180^0.

1. Introduction

Patrol vessel is an essential part of offshore security archipelago countries such as Indonesia. The main feature of patrol vessels is operating in rough waves during operation. Ship stability is one of the challenging aspects of high-speed craft because the ship has a small breadth that leads to small self-righting moments in roll motion. This situation could endanger the vessel when a vessel is rolling above 180^0; as a result, a ship can capsize due to losing a self-righting moment. Priohutomo has studied patrol vessels with control manoeuvering ships using an experimental approach in wave basins [1]. The study of the number of bilge keel in patrol vessels was done by Widyatmoko [2]. The study of ship construction and strength of patrol vessels has been conducted by Koostanto [3], moreover CFD simulation was performed by Samuel [4]. The effect of spray strip on on high-speed craft has been conducted by Samuel [5]. Self-righting moment of the patrol vessel was carried out by Putra using a numerical approach. The results showed self-righting moments could be achieved by extending the breadth of the upper deck structure [6]. Previously, the self-righting moment study was done using a numerical method using Hydromax [7]. It shows that the study of a physical model of patrol vessel with a self-righting moment is rolling above 180^0 still few. Thatcher has divided some remarks of self-righting methods into three methods, i.e., inherent stability self-righting, inflatable bag, and ballast movement [8]. Capsize is one cause of marine accidents in the world, as shown in Fig. 1 [9], although it is a very small portion based on Fig.1. Moreover, a patrol vessel is commonly used as a search and rescue (SAR) vessel; as a result,

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this vessel has to operate in a rough wave. Thus, the vessel could undergo rolling in extreme conditions (above 180^0).

This study aims to conduct self-righting moments in patrol vessels using an experimental approach, the ship's condition rolling above 180^0. Firstly, ship modeled in CAD model and calculation of the center of gravity (CG), Buoyancy (B), and metacenter (M) conducted in full scale. The next step is ship was scaled 1:27,4 and recalculated of CG, B, and M. Finally, an experiment was carried out in towing tank to verify self-righting moment is rolling 180^0. It was found the self-righting moment was proved to exist during rolling above 180^0.

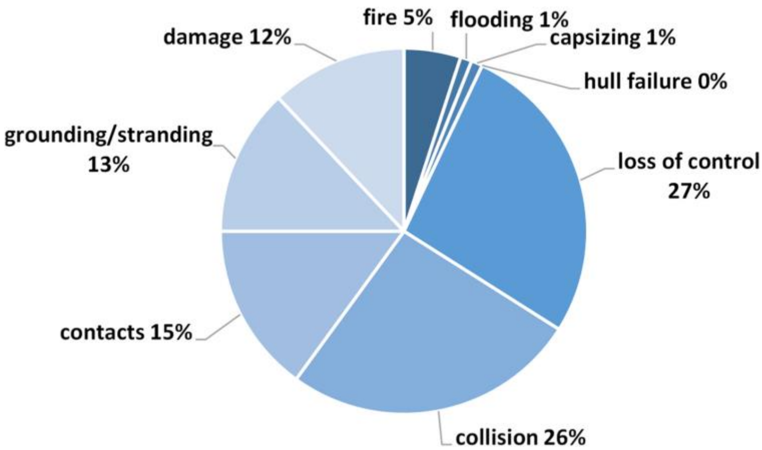


Figure 1. Marine accident of ship during 2011-2019 [10]

2. Methods

The experimental study was started scaled the full-scale model into a scale model (see Fig. 2), as shown in Table 1. Table 1 shows the dimension of the patrol vessel that will be modeled in the laboratory. The next step is to model patrol vessels using 1:27,4. In this study, the condition of the ship is the maximum load, which is a heavier weight, higher center of gravity, and a higher draft compared to other shipload conditions. LCG is a longitudinal center of gravity, and KG is the distance of keel to gravity.

Table 1. Principal dimension of patrol vessel

Principal Particular	Dimension	Scaled model
LOA	13,7 m	50,0
LPP	13,0 m	47,4
B	4,20 m	15,0
D	1,15 m	4,20
H	2,19 m	8,00
Displacement	26,023 ton	1268,606 gr
LCG	5,318 m	19,40 cm
KG	1,21 m	4,42 cm

Fig. 3 (a) shows a scale prototype model of the actual ship made using 3D printing. Fig. 3 (b) is the solid ballast for the prototype model to make the ship is in a maximum load condition and made the center of gravity according to the actual ship. Fig. 3 (b) shows the model of solid ballast placed at 14.55 cm from the AP. The position has been designed so that the prototype model has the same center of gravity as the condition of the ship with maximum load.

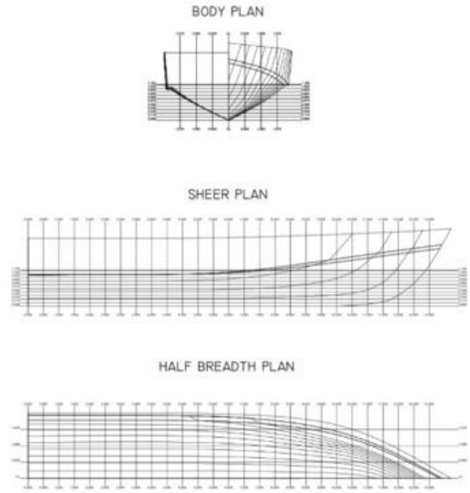
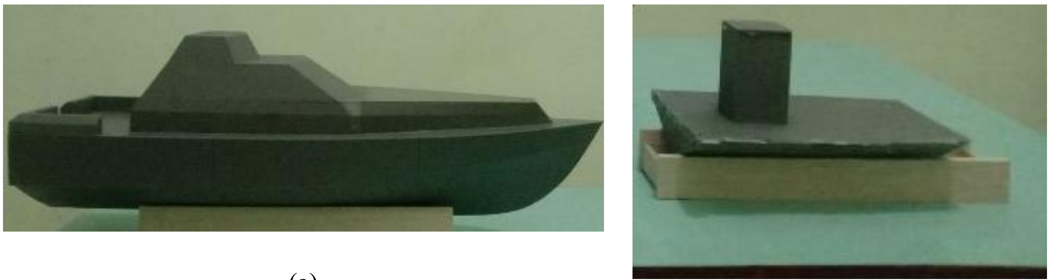


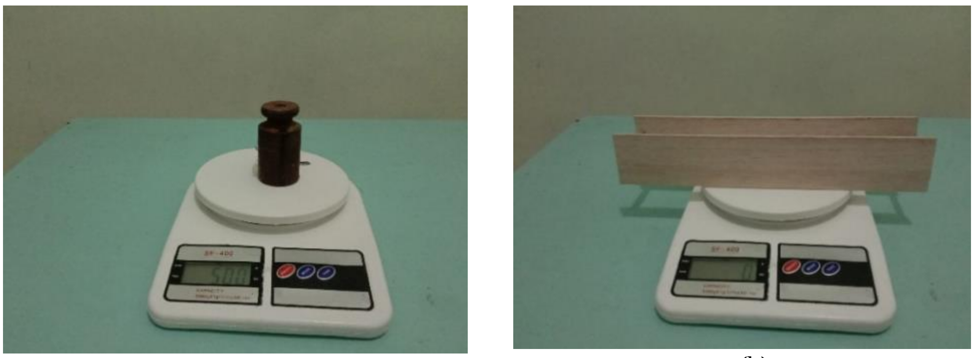
Figure 2. Lines plan of the patrol boat



(a) (b)

Figure 3. The modeled patrol vessel with a scale 1: 27,4.

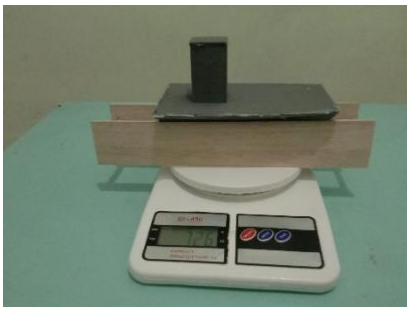
Fig. 4 shows a measurement of the weight of each part on the prototype model ship. Fig. 4 (a) is calibrating the scales. The purpose is to avoid errors in calculating the load. The calibration process uses a 500 gr load with a correction value of 0% showed in scale. Fig. 4 (b) shows the process of setting 0 gr when calculating the load using a seat booth. It shows the load of the seat booth is counted 0 gr. Fig. 4 (c) is the process of calculating the weight of the superstructure with the result is 159 gr. Fig. 4 (d) is the process of calculating the weight of the hull with the result is 377 gr. Fig. 4 (e) calculates the additional weight with the result 726 gr.



(a) (b)

(c)

(d)



(e)

Figure 4. Measurement of the physical model of the patrol boat.

The center of gravity is calculated using the moment calculation formula. Equation (1) is the equation for the moment of force measurement of the physical model of a patrol vessel.

$$CG = F \ x \ l \tag{1}$$

Where
F = Force (N)
l = arm distance (m)
F = m.a
Where: m = mass (kg); a = acceleration (m/s^2)

3. Results and Discussion

Table 2 shows the longitudinal center of gravity and transverse center of gravity calculation. Data of Weight is to obtain the center of gravity and the total weight of the prototype model. This calculation uses the formula moment of force.

Table 2. Calculation of the center of gravity and the total weight of the model

Item	m (gr)	F (N)	LCG (cm)	Moment LCG (N.cm)	KG (cm)	Moment KG (N.cm)
Hull	377.00	3694.60	19.39	71627.21	4.92	18184.82
Upper Deck	159.00	1558.20	22.13	34484.52	11.57	18022.14
Load	726	7114.8	18,77	133523.4516	2,63	18726.1536
Total	1262.00	5252.80	19.38	239635.186	4,44	54933.116

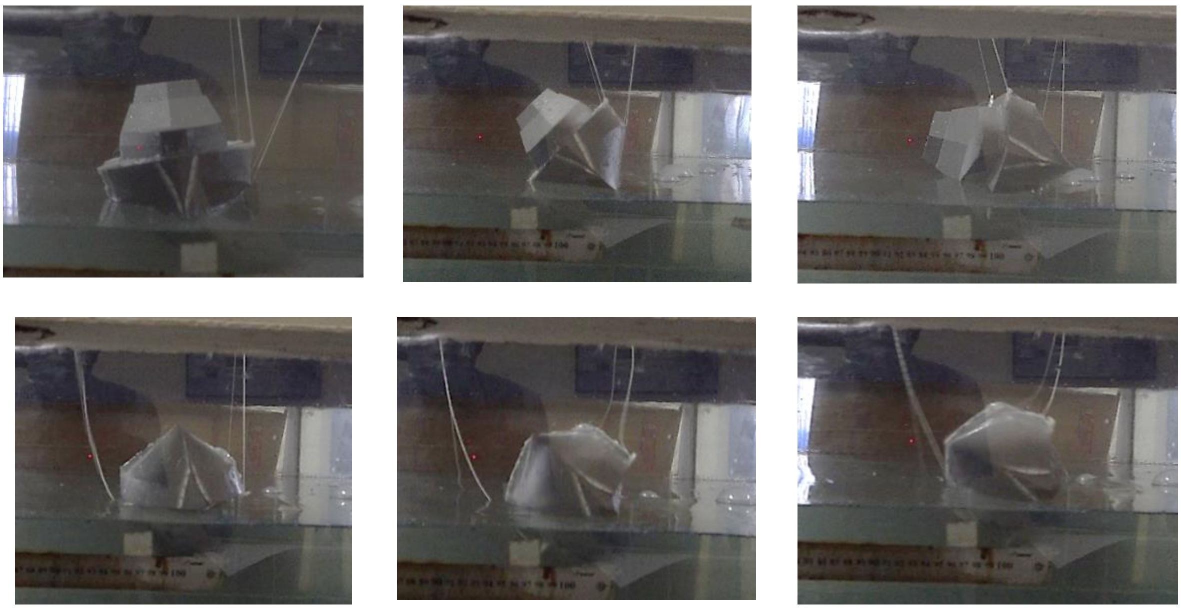
The results obtained from the calculation of the center of gravity and the total load of the prototype model are compared with the actual ship with maximum load conditions. Table 3 is a comparison of the calculation results with the actual ship in maximum condition with the aim of seeing the error value that occurs after the printing process and calculating the weight with a scale.

Table 3. Comparison calculation of center gravity

Item	Full scale ship	Scaled ship	Difference (%)
LCG	19,4	19,38	0,165%
KG	4,42	4,44	0,581%
Mass	1268,606	1262	0,363%

The result shows the comparison calculation value in Table 3. It shows an error value below 5% so that the prototype model can be used in the experiment. In this research, the test was set up in the towing tank, where the prototype of the model was placed on calm waves. In the first step, the prototype model is rolled over to an angle of 180^0 from the prototype model's initial position (0^0). When the prototype model has reached 180^0 position, the prototype model will be released freely. It can be seen that the prototype model can return to its original position, i.e., the initial position / 0^0 position. Fig. 5 shows the process of self-righting recovery experiment.

From Fig. 5, the ship can return to its original position without stopping between 0^0-180^0 after being overthrown 180^0. From these results, it can be concluded that the patrol boat has self-righting capabilities during rolling above 180^0.



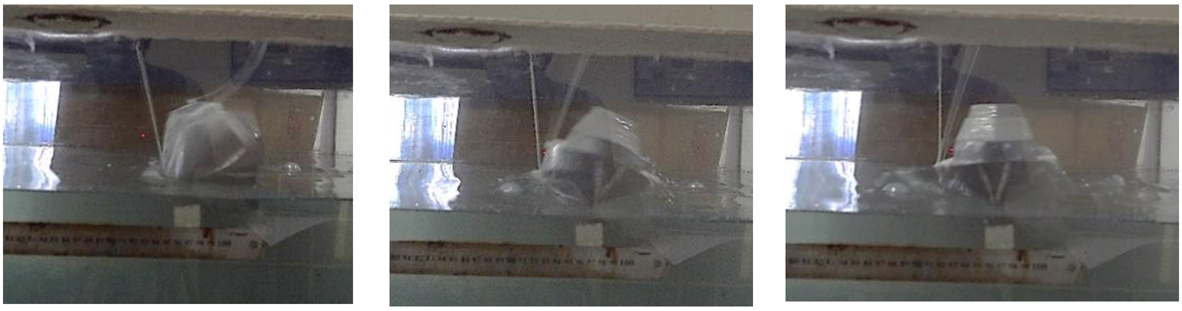


Figure 5. Self-righting recovery experiment

4. Conclusion

A verification test was successfully conducted to prove the self-righting capability of the patrol vessel. This verification was carried out using the experimental approach of making a prototype 3D printing model with a scale of 1:27,4. The principal dimension of ships Lpp, B, H, T, are 13.0 m, 4.2 m, 2.19 m and 1.15 m, respectively. This prototype ship was conducted in the maximum load of vessel that had been designed with a correction below 5%. Then the prototype model was tested for rolling 180^0. It was found that the prototype ship model was able to return to its original position. It was proven the patrol boats have self-righting capabilities based on experiment study. Future works of the numerical method of ship stability will be carried out to verify the present result.

5. Acknowledgments
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References

[1] K. Priohutomo, A.A. Masroeri and C. Permana 2017 Perancangan Kendali Manuver Untuk Menghindari Tabrakan Pada Kapal Patroli Cepat Berbasis Pengujian Model *Kapal: Jurnal Ilmu Pengetahuan dan Teknologi Kelautan*, **14**(3) p 71-78
[2] A. Widyatmoko, S. Samuel, P. Manik and A. Trimulyono 2021 Analisis Pengaruh Jumlah Bilge Keel terhadap Gerakan Rolling pada Kapal Patroli 14 m *Warta Penelitian Perhubungan,* **33**(1) p 1-10
[3] H. K. Koostanto, A. F. Zakki and S. Samuel 2021 Studi Perencanaan Konstruksi Dan Analisa Kekuatan Kapal Patroli 165 DWT Pada Perairan Indonesia *Jurnal Teknik Perkapalan*, **9** (1) p 91-104.
[4] S. Samuel, A. Trimulyono, A.W.B. Santosa 2019 Simulasi CFD pada Kapal Planing Hull *Kapal: Jurnal Ilmu Pengetahuan dan Teknologi Kelautan*, **16**(3) p 123-128
[5] S. Samuel, A. Trimulyono, P. Manik and D. Chrismianto 2021 A Numerical Study of Spray Strips Analysis on Fridsma Hull Form *Fluids*, **6**(11).
[6] A. B. C. Putra and H. Hasanudin 2019 Desain *Self-Righting Rescue Boat* Untuk Basarnas *Jurnal Teknik ITS,* **8** (2) p 99-105.
[7] A. Zuhdi, S. Sunaryo and M. Baqi 2014 Analisis Kemampuan *Self Righting* Kapal Model Tanpa Awak Dengan Pendekatan Stabilitas Menggunakan Hydromax Pro. Final Project *Naval Architecture Department University of Indonesia*
[8] K. C. Thatcher 2013 Self-Righting Craft Basic Principles And Design Requirements *The International Journal of Small Craft Technology*, **155** (B1): p B1-B11.
[9] D. Vassalos and D. Paterson 2021 Towards unsinkable ships *Ocean Engineering* **232**.
[10] Clarkson 2019 Shipping Intelligence Network. *UK Clarkson Research Service Limited*.