11th International Conference on Marine Technology
MARTEC 2018

THE DESIGN AND STRUCTURAL ANALYSIS OF A NON-SINKABLE SURVEILANCE VESSEL FOR THE FOREST DEPARTMENT OF BANGLADESH

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ABSTRACT

Sundarbans is a vast forest in the coastal region of the Bay of Bengal and considered one of the natural wonders of the world. Sundarbans contain the world's largest coastal mangrove forest, about 6,000 km^2 of which are located in Bangladesh and that is enriched with diversified flora & fauna. Forest Department is a government agency responsible for the protection and maintenance of forests and wildlife in Bangladesh. However, the forest officials placed at various locations engaged in duty for the protection of Sundarbans have had to embrace death due to ruthless situations created by possible invaders. For the protection of the inhabitants of Sundarbans, the duty officers and more importantly for the safety of the area itself, in this paper we are proposing the design of a non-sinkable surveillance vessel. The objective of this vessel is not only to safeguard the area, but it should be able to fulfill any special purpose related to deep sea operation, be used as a jetty platform where required and also to be converted to any kind of vessel when required. We have selected a chine shaped Catamaran hull. Catamaran reduces the drag significantly and ensures lesser frictional resistance. Multihull design eliminates the need for a keel counterweight, as the same purpose (righting the ship) is served by the hull spacing. The use of chine gives the vessel a high transverse stability so the mooring will be easier as tendency to heel over is restricted significantly. An attempt was made to design a vessel which is different from the conventional pontoon type design. The survival capacity, the sustainability, stability and the towing capability is believed to be fairly high, making it a unique design. In this paper the design of a non-sinkable surveillance vessel to be used by the forest department, is being proposed.

Keywords*: Catamaran hull, Chine, Non-sinkable*

1.0 INTRODUCTION

Sundarbans, located in the south-west of Bangladesh between the river Baleswar in the East and the Harinbanga in the West, adjoining to the Bay of Bengal, is the largest contiguous mangrove forest in the world. Lying between latitude 21° 27′ 30″ and 22° 30′ 00″ North and longitude 89° 02′ 00″ and 90° 00′ 00″ East and with a total area of 10,000 km^2, 60% of the property lies in Bangladesh and the rest in India. Sundarbans is of universal importance for globally endangered species

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including the Royal Bengal Tiger, Ganges and Irawadi dolphins, estuarine crocodiles and the critically endangered endemic river terrapin. It also provides sustainable livelihoods for millions of people in the vicinity of the site and acts as a shelter belt to protect the people from storms, cyclones, tidal surges, sea water seepage and intrusion. The area provides livelihood in certain seasons for large numbers of people living in small villages surrounding the property, working variously as wood-cutters, fisherman, honey gatherers, leaves and grass gatherers.

The property is currently well managed and regularly monitored by established management norms, regular staff and individual administrative units. "Forest expansion, biodiversity conservation, poverty alleviation and wildlife conservation through active participation of people" is the mission of the Forest department of Bangladesh. And so round the clock, surveillance is present surrounding Sundarbans. For the protection of the inhabitants of Sundarbans, the duty officers and more importantly for the safety of the area itself, the proposed non sinkable surveillance vessel is thus very significant. A number of papers published on Catamaran hull [1] for increased stability and sustainability have been taken into consideration while deciding on taking so for the proposed vessel. Also, impact loading is tested with a $52x10^6$ N force [3] to prove the non-sinkability.

2.0 DESIGN CONDITIONS AND PARAMETERS

Various conditions were considered to reach the principal particulars and hull shape of the proposed vessel, which are described as follows:

2.1 Purposes to serve

At the beginning of the work, the aim was clear to design a vessel which can –

- Absorb the shock wave generated by the direct impact of bullet on its body
- Be able to tow more easily
- Less power required to tow
- Be perfectly stable at deep sea and in adverse weather and sea conditions

Moreover the objective was not to constraint the vessel for surveillance purpose only; rather we intended to design a multitasking vessel which can be used in other purposes; in and when required. Such as –

- Fulfilling any special purpose related to deep sea operation
- Carry out any kind of succor mission
- Used as a jetty platform where required
- Converted to any kind of vessel in future

2.2 Principal Particulars

The principal particulars of the non-sinkable surveillance vessel are as follows:

Length Overall (only hull)	Breadth:	Depth:	Design Draft:	Displacement:
51.00 m	12.00m	5.50 m	2.20 m	387.1 tonne

2.3 Keeping a minimum freeboard

The amount of freeboard which a vessel has is a measure of the amount of buoyancy which is left above the water line to support the vessel in case of bad weather or damage. This buoyancy is called reserve buoyancy. Minimum freeboard is required at all times to prevent the vessel being swamped and overwhelmed. For ocean going vessels, it is important to note that those structures above the waterline that are not watertight will not contribute to the reserve buoyancy of the vessel. This is an important measurement since it determines how it will perform in wind and waves. For stability and reserve buoyancy purpose it is necessary to maintain minimum freeboard in NSSV.

2.4 Ambient conditions

The surveillance vessel is to be designed to operate in the moist and humid tropical environment of Bangladesh. The conditions will be as follows:
a. Air temperature: +5ºC to +45ºC.
b. Sea water temperature: +5ºC to +32ºC
c. Relative humidity: Up to 98%.
d. High mud (suspended) content in seawater in coastal areas.

2.5 Sea keeping ability

- The stability of the vessel for all operational condition of loading will conform to the criteria recommended by IMO and Government of Bangladesh.
- The hull form shall be so designed as not to cause any undue trim under all possible conditions of sustainability. Some ballast water may be required in the tank to ensure a level trim.
- The vessel should be able to remain stable & recoverable at a number of damage conditions, even any adjacent compartments are flooded.
- The vessel should be able to sustain at moored condition upto sea state 5 (wave heights: 2.5 – 4.0 m) and upto Beufort scale 6 (wind speed: 22 – 27 knots).

3.0 HULL FORM

3.1 Catamaran Hull

Displacement hulls, the most common shapes for single hull craft is supported on the water entirely by buoyancy effects which creates more resistance by introducing a hydrodynamic drag barrier. But Catamaran is very thin and pointed hull design; in a word it is a slender hull form which reduces the drag significantly. It ensures lesser frictional resistance and enables the craft to tow more easily. Multihull design eliminates the need for a keel counterweight, as the same purpose (righting the ship) is served by the hull spacing. This further reduces drag and displacement, enabling designers to use more sail per foot of the boat. Because of its wide beam length, it becomes practically difficult to turn over; giving the craft more stability and enables it to sustain in rough sea conditions. This also allows the craft to gain more power from heavy gusts as they do not tend to heel over like monohulls do. To summarize the reasons behind selecting catamaran are:

- Easily towed requiring lesser power.
- Very hard to roll due to transverse stability is very high.
- Large deck area to facilitate all the arrangement like accommodation.
- As transverse stability is high, mooring is easy, less tendency to heel over.
- Can be converted self-propelled vessel and can perform heavy duties at adverse weather and sea condition if necessary.
- Less drag means more speed at less power which enables it to perform any succor mission rapidly.
- Void tanks can be used for carrying goods/relief.

3.2 Energy Absorption by Catamaran

Catamaran hull form shown in Figure 1 allows an open space between the two hulls. After direct impact of the missile [2] some energy is absorbed by hull structures by the means of frictional and elastic energy. Then some portion of the impact force is dissipated through the space between the hulls which makes the damage less severe in the other hull. It is one of the reasons to select twin hull.

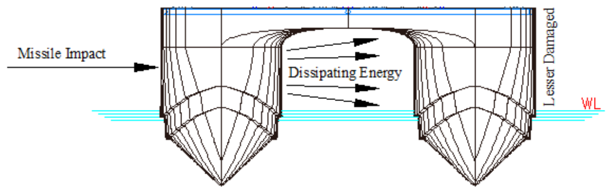


Figure 1: Energy Dissipation by Catamaran hull

3.3 Introduction to Chine

With the catamaran hull an upper chine and a lower chine is introduced (Shown in Figure 2) in designing the form. This kind of chine hull is used in warcrafts where more transverse stability is required.

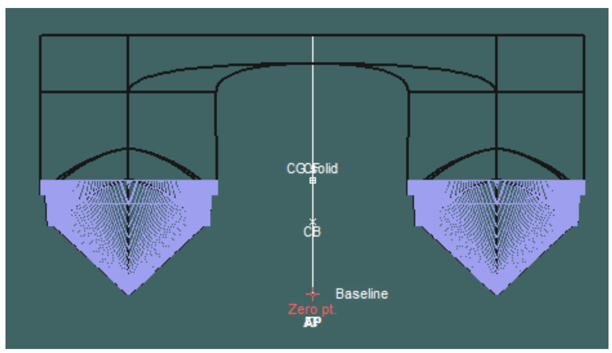


Figure 2: Upper and Lower Chine

Thus in this case also the use of two (2) chines gives the vessel –

- A high transverse stability so the mooring will be easier as tendency to heel over is restricted significantly.
- Provides additional lift force, which could help to tow the vessel.

4.0 SIMULATION DATA

Finite element analysis is universally recognized as the most important technological breakthrough in the field of engineering analysis of structures. In order to calculate the stress and damage characteristic of Non-Sinkable Surveillance Vessel, finite element analyses were carried out by using the finite element code and engineering simulation software, ANSYS**.** Numerical computations have been carried out based on 3D finite element method. The force is assumed in this simulation is $52x10^6$ N [3]. Also this impact force has been doubled and applied it in the simulation process.

4.1 Model Generation

At first the model was generated and shown in Figure 3, which is just a portion of the vessel where it was assumed the impact force to hit the body. Waterline was set and point was fixed for impact.

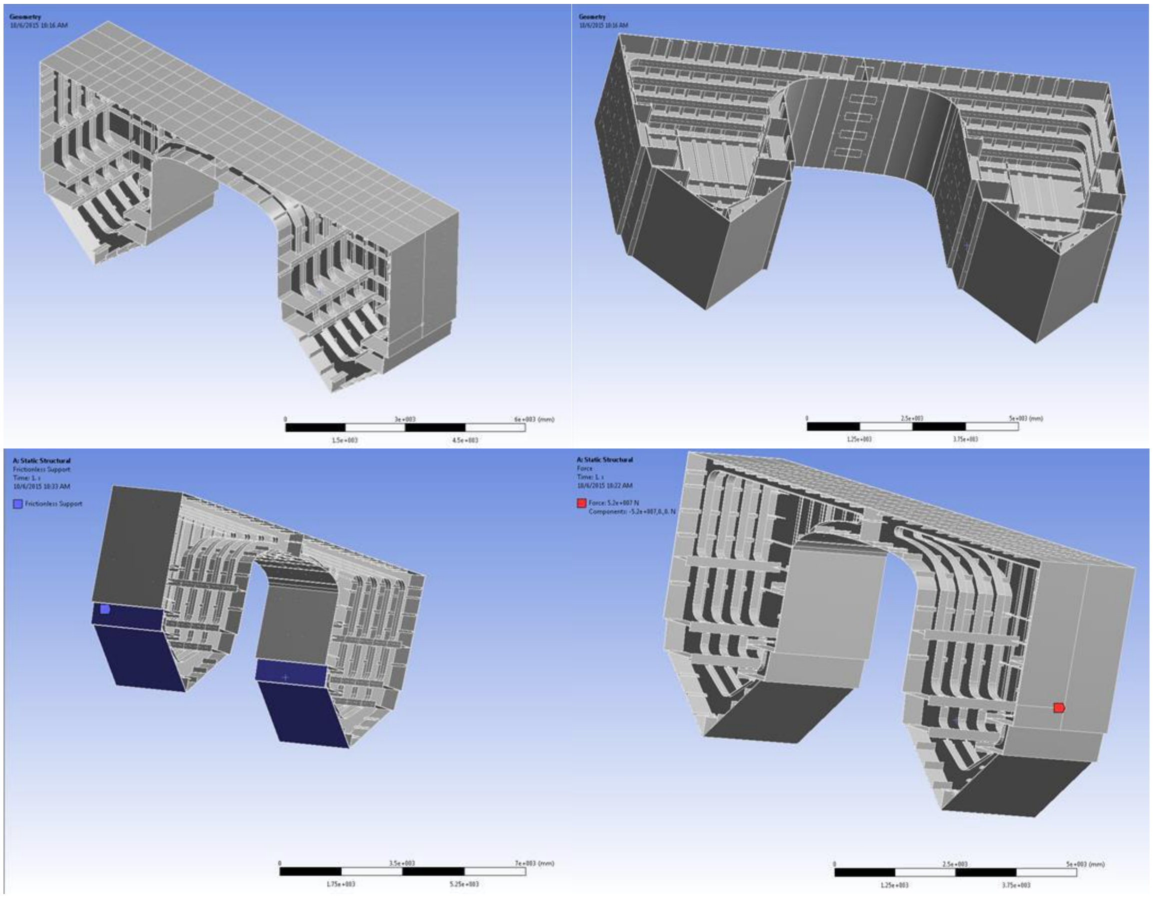
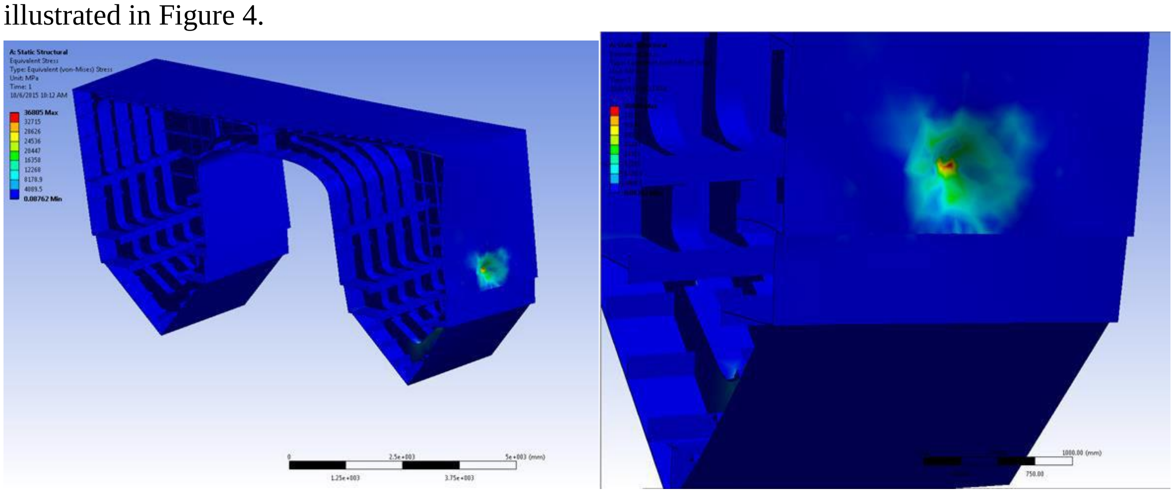


Figure 3: Model Generation and fixing probable point of impact

4.2 Structural Analysis with $52x10^6$ N force

As the shock wave energy generated by the impact force through the direct hitting on the vessel the structural analysis was performed based on the force considered $52x10^6$ N. The results are illustrated in Figure 4.



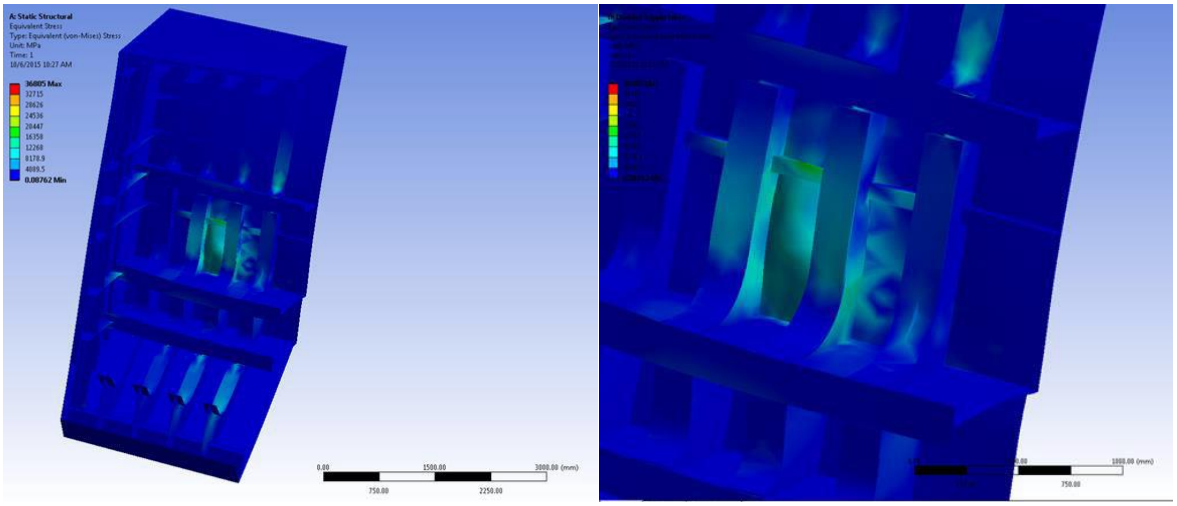
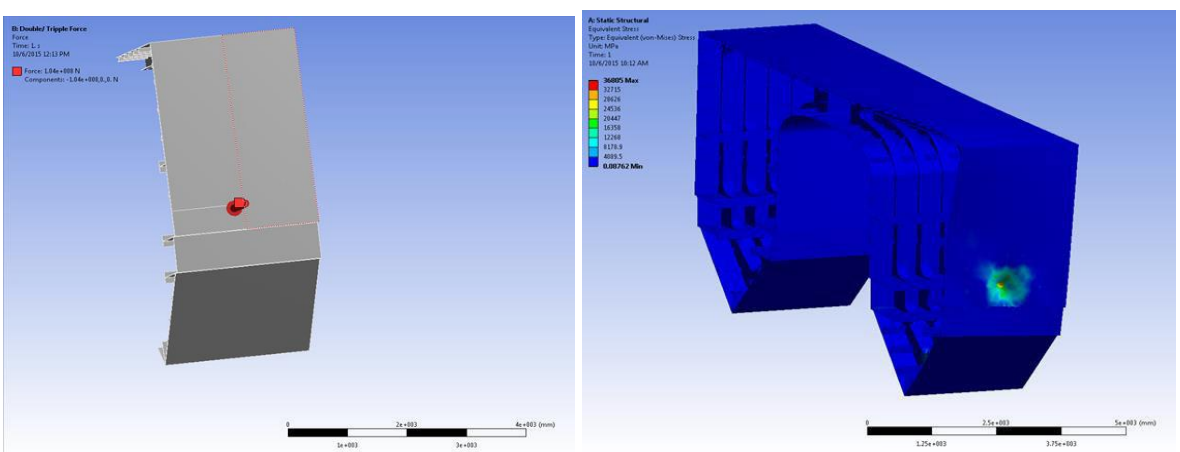


Figure 4: Simulation result of $52x10^6$ N force

4.2 Structural Analysis with $2x52x10^6$ N force

After gaining the satisfactory result with 52x106 N forces, then double the force and began simulating again. Even so the damage propagation was not so severe. The result with 2 X ($52x10^6$) N force is illustrated in Figure 5.



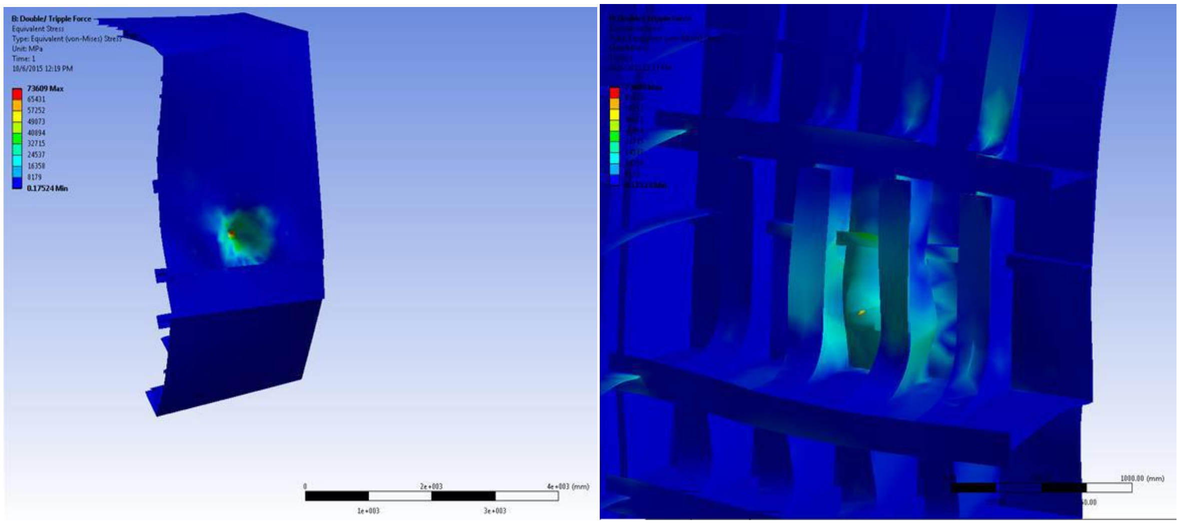


Figure 5: Simulation result of $2x52x10^6$ N force

5.0 STABILITY ANALYSIS RESULTS

Hydrostatic analysis and cross curve stability analysis was performed for three trim conditions: 0.5m by stern, no trim and 0.5m by aft. Also limiting KG analysis and Equilibrium analysis were done using Maxsurf stability enterprise module, and finally the results obtained from large angle stability analysis were considered acceptable because of compliance with the criterion (Shown in Table 1) of IMO regulation.

Table 1: Intact stability results

Code	Criteria	Value	Units	Actual	Status	Margin%
A.749(18)Ch3- Design criteria applicable for all ships	3.1.2.1 Area 0 to 30	0.0550	m./rad	1.2309	Pass	+2137.73
A.749(18)Ch3- Design criteria applicable for all ships	3.1.2.1 Area 0 to 40	0.0900	m./rad	1.8396	Pass	+1943.98
A.749(18)Ch3- Design criteria applicable for all ships	3.1.2.1 Area 30 to 40	0.0300	m./rad	0.6088	Pass	+1929.35
A.749(18)Ch3- Design criteria applicable for all ships	3.1.2.2 Max GZ at 30 or greater	0.200	m	3.629	Pass	+1714.50
A.749(18)Ch3- Design criteria applicable for all ships	3.1.2.4 Initial GMt	0.0150	m	10.639	Pass	+6926.00

Based on the analysis using structural analysis software, the maximum and minimum damage propagation was found at 15 m and 5 m respectively for the impact force varying from 52x106 N to 2X 52x106 N. The following damage cases are based on these analyses.

Table 2: Damage cases

Damage case	Compartment ID	Explanation
DCase 1	Tank001(P)	Void
DCase 2	Tank001(P) & Tank003(P)	Void
DCase 3	Tank003(P)	Void
DCase 4	Tank003(P) & Tank005(P)	Void
DCase 5	Tank005(P)	Void

DCase 6	Tank005(P) & Tank007(P)	Void
DCase 7	Tank007(P) & Tank009(P)	Void
DCase 8	Tank007(P) Tank009(P) Tank011(P)	Void
DCase 9	Tank009(P) Tank011(P) Tank013(P)	Void
DCase 10	Tank013(P) Tank015(P) Tank017(P)	Void
DCase 11	Tank015(P) Tank017(P) Tank019(P)	Void
DCase 12	Tank017(P) Tank019(P) Tank021(P)	Void
DCase 13	Tank021(P) Tank023(P)	Void
DCase 14	Tank023(P) Tank025(P)	Void
DCase 15	Tank025(P) Tank027(P)	Void
DCase 16	Tank023(P) Tank027(P) Tank029(P)	Void

For all the damage cases, the results were acceptable because of compliance with the following IMO criterion:

Table 3: Damage stability results

Code	Criteria	Value	Units	Actual	Status	Margin%
Regulation 28 GZ-based	28.3.1 Ratio of equi angle at final waterline (no DF)	100.00	%	10.17	Pass	+89.83
Regulation 28 GZ-based	28.3.2 Equi heel <=25 or <=30 if no DE immersion	100.00	%	12.62	Pass	+87.38
Regulation 28 GZ-based	28.3.3 Range of positive stability including DF	20.0	Deg	22.0	Pass	+10.15
Regulation 28 GZ-based	28.3.3 Residual righting lever	0.100	M	2.917	Pass	+2817.00
Regulation 28 GZ-based	28.3.3 Area under GZ curve	0.0175	m.rad	0.5432	Pass	+3004.17

6.0 CONCLUSION

The structural analysis was performed by targeting the impact force on the naked area of the body which is between two (2) web frames; where the energy absorption capability is at the lowest. But still based on the analysis and the simulation data obtained, the result is much satisfactory. The damage propagation shown here is at a tolerable side. Although the force which we used may vary from the actual impact force but nevertheless the outcome results itself yields the vessel sustainability. For the protection of Sundarbans, the proposed non sinkable surveillance vessel will play a vital role. And also, it will not only be used for the purpose of surveillance, but it will be able to fulfill any special purpose related to deep sea operation and also to be converted to any kind of vessel when required

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