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HATCH COVER ANALYSIS OF CAPESIZE BULK CARRIERS AND SUGGESTIONS FOR ALTERNATE MATERIALS

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ABSTRACT

Hatch cover failure leads to flooding of the forward cargo compartment and occasionally results in fatal casualty. The foremost hatch cover and the next one within 25% length of the vessel are prone to the impact by shipping of green water. The loss of hundreds of bulk carriers with the precious lives is a nightmare to both designers and insurers. The tail of Rayleigh distribution showing the extreme rare wave heights is a matter needed great attraction of designers and analysts. Though rare, the extreme wave heights are responsible for the failure of bulk carrier ships. The tricky point is that the more we increase the strength of the hatch cover the more is its self weight. The position of vertical centre of gravity of vessel goes up and that is not desirable for commercial ships in many aspects. Deficiency in the scantling of bulk carrier covers is brought out in this paper. Suggestions to use better material having higher strength to weight ratio is made. The use of composite reduces maintenance costs and improves structural and operational performance.

Keywords: *Hatch cover, shipping green water, wave breaking, composite laminate, flooding, delamination.*

1. INTRODUCTION

The pathetic situation in many marine accidents is that the vessel broke up sinking immediately before the Master could send a distress massage. A recent observation on the seas reveals a fact that there is possibility of waves with crest to trough of 20 to 30 meters [1]. Such waves of non-linear nature encounter the moving ship and the mass of the water above the main deck is broken and collapsed onto the deck and hatch cover of the vessel. During the head-on encounter with the incoming waves the ship may be heaving, pitching or undergoing a coupled motion. The collapsed wave on top of the hatch meets the moving ship with high relative velocity and giving more inertial force onto the deck. The dynamic force of wave impacts should also be considered in the structural analysis of the deck, hatch covers, hatch coamings and other vulnerable areas. Current design criteria generally consider only 11m wave height as per IACS recommendation [3]. The authors also suggest that the IACS recommendation 34 should be modified to consider more possible height of waves for safe marine operations. Wave impacts in the closed hatch covers of bulk carriers can induce extremely large impact pressures and can cause capsize and loss of the ship in no time. As per Rosenthal [7] a highest wave of about 28 meters was found in the South Atlantic The hatch cover of a capsize bulk carrier ships are analyzed here for both UR S 21 and UR S21+40% extra loads. Is the extra load is only 40%?. More loads are also to be considered along with a strong hatch cover system especially within 25% of the length of the ship from the most forward part. Can we manage the hatch cover problems using ordinary steels? Is there any alternate material possible? Such critical queries are to be addressed by the researchers working in the field.

A typical hatch cover of a capsize bulk carrier is considered for this study. The hatch cover is designed in accordance with IACS rule URS21. A 40% higher load would mean approximately 10-15% additional to URS21 weight. It is better to reduce the weight for the parts of hull above the load water line. Hatch coamings and covers made of steel are at levels above the main deck and challenging the righting arm stability. The worse is the case when their own masses are increased to protect the ships from unforeseen wave conditions.

With a view to reducing structural weights, composites are being tried now a day.

2. HATCH COVERS LOCATION AND DETAILS

Hatch covers are designed as per classification rules. But when it comes to ship strength, there are many challenges. The strength and weight of hatch covers are mutually related. Weight directly affects the freight capacity and hence returns for the ship operator. The hatch system design has to outlive the hydrodynamic loads Sea wave profiles converted into time domain will predict a wave even 2.4 times the significant wave height. This is reported as per Rayleigh distribution of wave heights [1].

Table 1 shows the particulars of the vessel considered. Figure 1 shows the plan view of the hatch cover. The size of Hatch cover No. 1 is the foremost one and17 m long and 15 m width roughly. The size of the second hatch cover (Hatch cover no.2) is 20m long and 15 m width. Hatch cover No. 1 has a steel weight of 270 kg/m^2 and that of no. 2 has a steel weight of 220 kg/m^2. Hatch cover no. 1 is stiffened for a load of 6- 6.5 T/m^2 and the hatch cover No. 2 is stiffened for a vertical load of 4 - 4.5 T/m^2.

Table 1. Main Particulars of Capsize Bulk Carrier

Item	Dimension
Length Between Perpendiculars	271.0 m
Breadth moulded	45.0 m
Draft	18.15 m
Depth moulded	24.6 m
Displacement	189197.0 Tonnes

In this study three different sections are taken from the hatch cover and analyzed under three different load conditions (2.8, 3.5 & 4.5 T/m^2).Thereafter, a 40% extra load condition was also considered. First a section containing longitudinal stiffener was considered and the analysis for 2.8 T/m^2 was done and then repeated analysis for a load of 3.5 and 4.5 T/m^2 respectively. Thereafter, the load was increased to 40% and the weight of the hatch cover up to roughly 15% to respond to this load. Then another sections containing side girder and centre girder also considered for the analysis. The sectional details of the girders and ordinary stiffener are as shown in Figure 2.

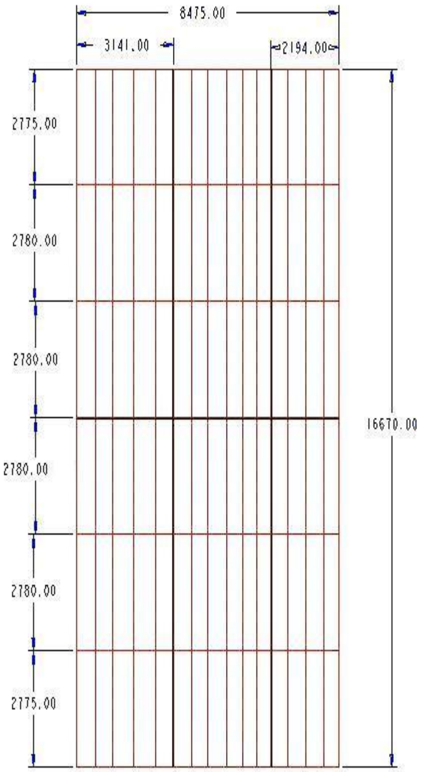
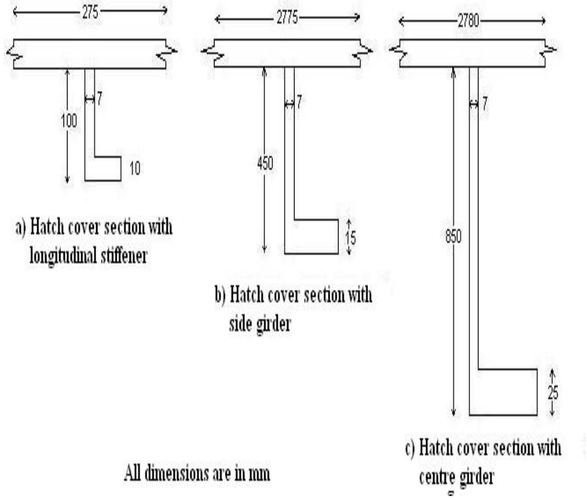


Figure. 1 Plan of Hatch Cover of Capesize bulk carrier



a) Hatch cover section with longitudinal stiffener

b) Hatch cover section with side girder

c) Hatch cover section with centre girder

Figure. 2 Sectional details of girders and stiffeners.

Study of hatch covers is very important as deck flexing could 'spring' this stiffened panels followed by water entry, rapid flooding and capsizing. The analysis is started with a load corresponding to 2.8T/m$^{2.}$ This is for a wave crest of height roughly 2.8m above the hatch cover. As per Figure 3, modeling and analysis using ANSYS is done and the results are discussed, maximum equivalent stress of 57.229 MPa is occurred at the node number 4338. The maximum centre deflection is seen to be 0.599961 mm, which is well within the design value provided by any codes for the end conditions assumed and the same for this is fixed supports. The loading is considered as equivalent static one due to a breaking wave producing a head equal to the height of the wave crest above the hatch cover. Similar approach is adopted by other analysts. Higher load cases were analyzed and purposely avoided here in view of optimization of space.

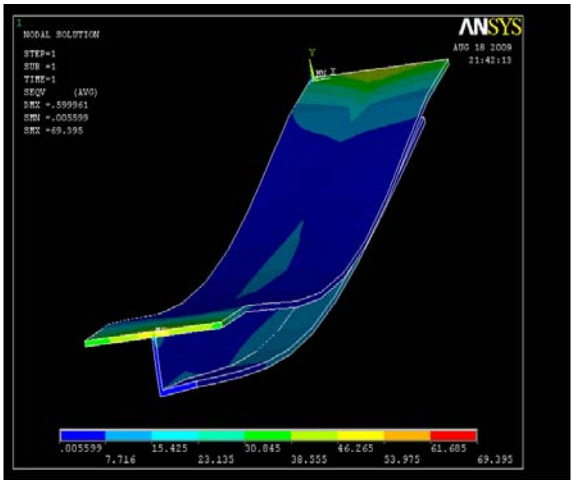


Figure 3 Analysis of hatch cover section with longitudinal stiffener subjected to 2.8T/m^2.

3. DESIGN LOADS

When the moving ship encounters head-on waves, there is relative upward motion of the ship with respect to the wave. The rising forward part of hull in pitch or coupled pitch-heave motions give rise to more accelerations and the hatch cover and deck meet the falling water mass, from the broken wave in an extreme, cause immense load on the hatch cover and deck. Nestegard and Krokstad [4] studied on water impact on deck. Search of available literature shows that the pressure on top of the hatch cover may be calculated as follows.

$$P^d = k^{dyn} . \rho .g. (k^{nl}.relu6-(h-T)) \ [kN/m^2] \quad ------ \quad (1)$$

Where:

k^{dyn} = dynamic factor relative to static pressure height.(Taken as 1.4)
k^{nl} = non-linear factor on relative motion for point 2
ρ = 1.025 tons/m^3
g = acceleration due to gravity, 9.81m/sec^2
h = height from base line to hatch cover.
T = draft at the hatch cover
relu6 = linear relative motion in head sea at selected point in hatch cover1 at centre line.

Substituting suitable values in Equation (1) the design pressure is calculated approximately as 5 T/m^2 for world wide and 6.3 T/m^2 for North Atlantic Sea.

4. APPLICATION OF COMPOSITES

The feasibility of application of composites in vulnerable parts of hull was established by Hackman Sandel and Kockums AB [2]. Although, much weight saving is possible for hatch covers having good strength to counter the load due to shipping green water or wave breaking, transverse bulkhead to withstand grain load will be more massive and bulky. This issue may be dealt with using a composite having better properties**.** For the same load the flexural rigidity of composite materials will be a few times (multiplication by a factor) that of the steel. Deflection for the same load will be more for the case of composites. This cannot be accepted for longer marine vessels. As the elastic modulus is only a fraction of steel the section modulus has to compensate for the total flexural rigidity or EI value. However hatch cover can be made with higher section modulus as it is just a cover. Honey combs and sand witch models discussed by Hackman Sandel and Kokums AB [2] are feasible. Scott and Somella [5] discussed in detail the feasibility of glass reinforced plastic in cargo ship. Costly fibers can be used to increase the strength to weight ratio, depending on the situation. With proper fiber orientation we can get desired strength and different lamina can be stacked together to give sufficient strength. The factors such as the choice of fiber and the resin, fiber volume fraction, fiber orientation, ply stacking sequence and number of plies and very important design drives to the composite structure**.**

Thickness of ply depends on the fiber volume fraction and we can get accurate value from design chart.

In this study three different load conditions [2.8, 3.5&4.5T/m^2] are considered. This hatch cover consists of four different laminate (high strength carbon-epoxy, S-glass epoxy, Kevlar epoxy and high strength graphite epoxy).

Bottom layer is S-glass epoxy named as material 3. Next one is E-glass epoxy, Kevlar-epoxy and upper layer is high strength carbon epoxy.

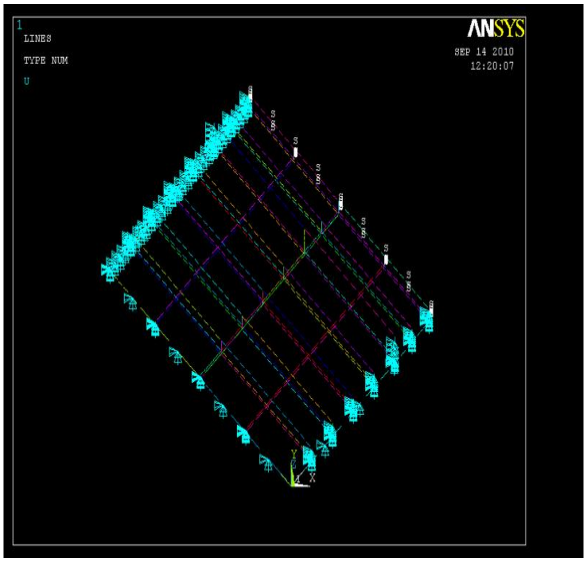


Figure 4. Finite element modeling of Composite plate with boundary Conditions.

To reduce the delamination area in a composite plate stitching through the thickness is also required [6].

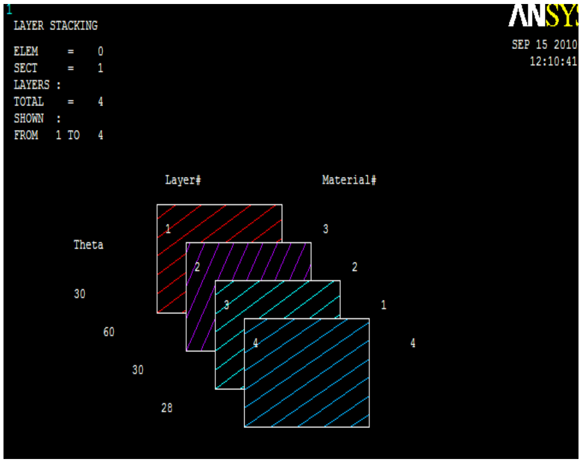


Figure 5. Orientation of fiber

Stiffener is also replaced with graphite-epoxy composite. For 4.5 T/m^2 load a composite plate with stiffener is modeled for folding type hatch cover having dimensions 2775 and 8474 mm. For each layer maximum stress and strain calculated. Thickness of each ply is 9.5 mm. Fiber orientations are 30°, 60°, 60° and 28° in order from bottom to top for plate and 0° & 90° for stiffeners.

From Figures 6, 7, 8, 9, 10 & 11 it is clear that all the stresses developed are less than the permissible stresses, for the composite materials .

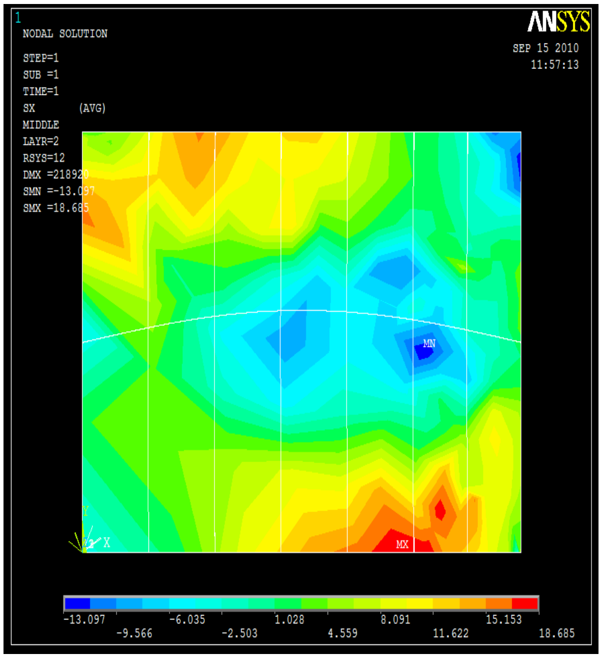


Figure 6.Normal stress in fiber direction material 2.

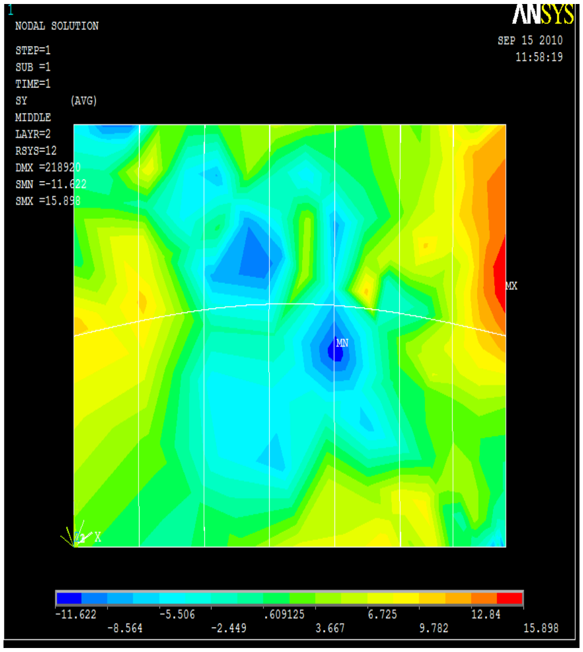


Figure 7. Shear stress in material 2.

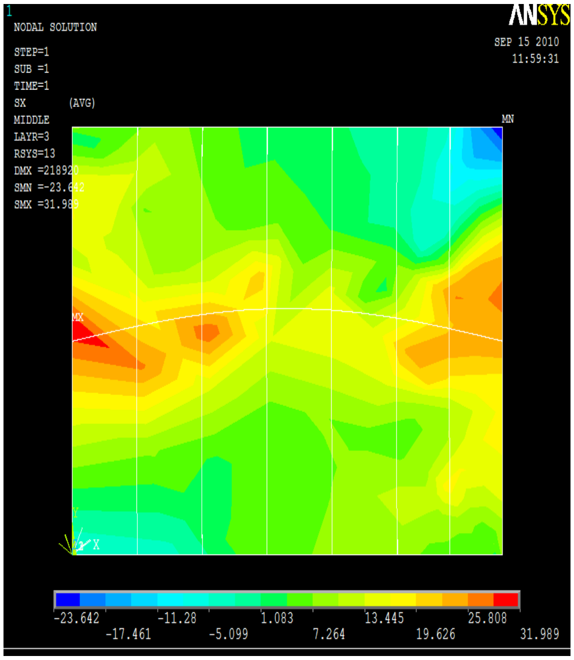


Figure 8. Normal stress in fiber direction in material 1.

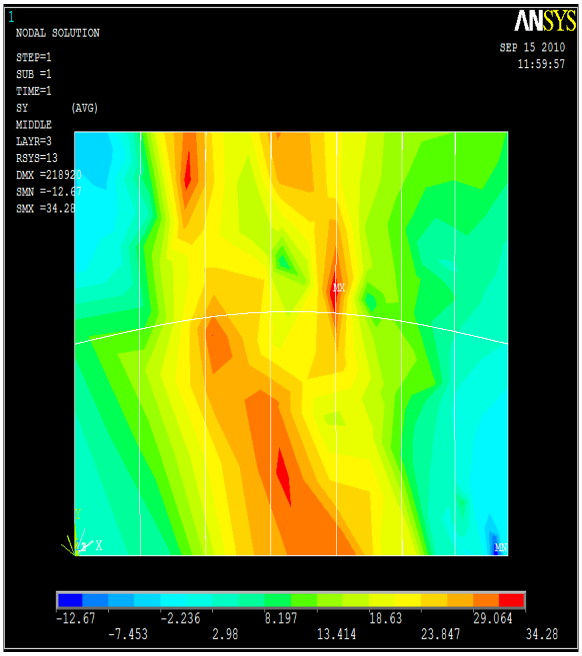


Figure 9. Normal stress in perpendicular to fiber direction in material 1.

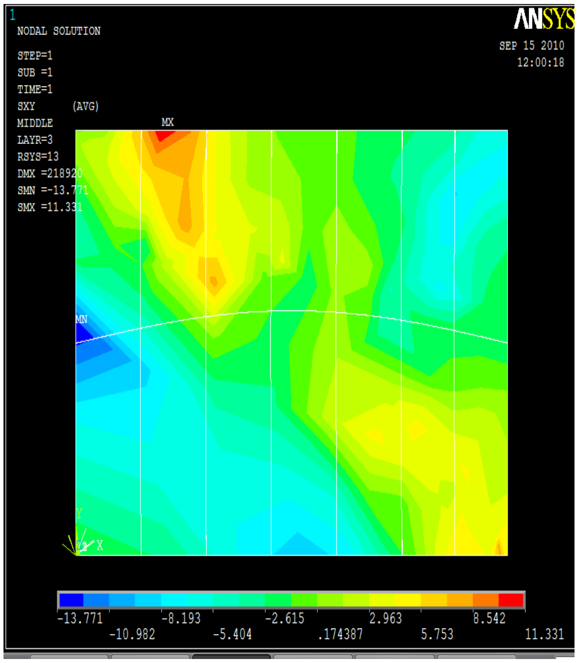


Figure 10. Shear stress in material 1

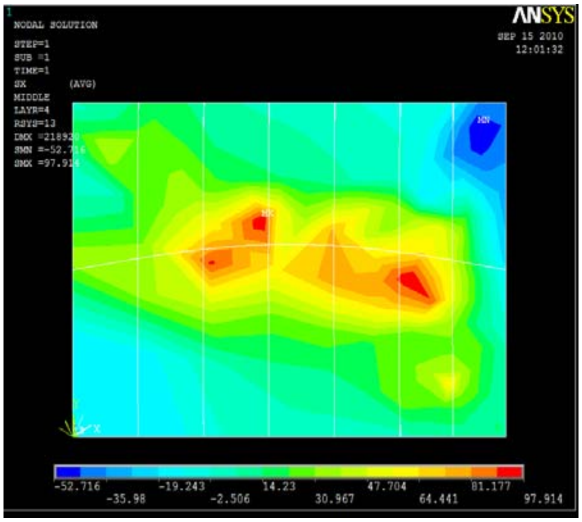


Figure 11. Deflection at middle of plate

5. CONCLUSION

From the above analysis we can conclude for almost all cases the equivalent stress are well below the ultimate strength of the material that is high strength low alloy steel. The end connections assumed for centre and side girders are simply supported and in actual scenario it may not be true. It may not be fixed too.

There will be some condition in between the fixed and simply supported ends.

The reduction in the topside weight would provide increased payload and better sea-keeping of the ship. Composite laminate is proposed for the same. A composite material, which is free of corrosion, is desirable for marine structure. The results of the detailed analysis will be discussed in the main paper. SCRIMP and resin transfer moulding processes can be used for high quality composite production and consideration of low safety factors for fabrication.

Here feasibility of using of composite materials is proved with folding type hatch cover analysis made up with hybrid laminate. After comparing the average density of laminate with steel it is found that composite structure weight is 0.56 of corresponding steel hatch cover weight. It is hoped that Bangladesh and other countries dealing with marine transportation will appreciate the ideas raised in this paper.

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