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# Optimisation of Weight and Strength of Ship Hatch Cover

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## Abstract

According to the increase of the operating cost and material cost of a ship due to the change of inter-national oil price, a demand for the lightening of the ship weight is being made from various parties such as shipping companies, ship owners, and shipyards. To satisfy such demand, many studies for a light ship are being made. As one of them, an optimal design method of an existing hull structure, that is, a method for lightening the ship weight based on the optimization technique was proposed in this study. For this, we selected a hatch cover of a bulk carrier as an optimization target and formulated an optimization problem in order to determine optimal principal dimensions of the hatch cover for lightening the bulk carrier. Some dimensions representing the shape of the hatch cover were selected as design variables and some design considerations related to the maximum stress, maximum deflection, and geometry of the hatch cover were selected as constraints. In addition, the minimization of the weight of the hatch cover was selected as an objective function. To solve this optimization problem, we developed an optimization program based on genetic algorithm. By using this, weight is reduced by 40%. Optimized dimensional parameters are considered in the analysis to find out the structural behavior.

*Key Words: Ship Hatch Cover, Genetic Algorithm, Optimization, maximum stress, maximum deflection*

## 1. Introduction

Ship designed to transport forest products, bulk cargos, unitized cargoes, project cargoes and containers. The vessel is typically fitted with two Gantry cranes for self-loading and unloading, with a typical SWL (safe working load) between 30 and 80 tons. Hatch covers for holds are opened and closed by mean of gantry crane. Space on those hatch covers can also be used to carry containers, lumber or project cargoes. The hatch cover has to be weatherproof and has to remain so when conditions change as a result of waves, temperature and cargo. The main aim or objective of this thesis is to design and simulate the hatch cover, using different materials and loading while placed on ship.

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Different loading, different materials and different suspension shapes are considered top run the analysis. The following methodology has been proposed to design a shoe sole and heel.

Consider any hatch cover

1. Find accurate dimensions of the hatch cover
2. Research the comfort and weight of hatch cover structure
3. Gather different types of materials used for the shoe in the present market
4. Different models with different shaped hatch cover should be modeled using CATIA software
5. by maintaining accurate and same dimensions
6. Using ANSYS software we have to perform the analysis by considering different
7. Loadings.

With these output we have to compare to find out optimum material and geometry shape.

From above mentioned, we have to follow the above steps.

### *1. 1 Problem definition*

Nowadays, hatch covers are an integral part for the marine ships and are used for safety of goods. Opening and closing of hatch covers are very critical task in marine industry due to heavy weight. To avoid such problems, these days, and different companies are using different research on hatch cover using CAD and FEM techniques. These companies are considering the real time conditions, trial and error process and developing different shapes and releasing the best cover to the market. From this, the company should bear cost and time at any time. To reduce the cost and time, in this thesis finite element method has been considered. Using this, we have to analyze the required hatch cover structure and their strength, stresses and deformations can be gained as output to find out the optimum body.

## 2. Literature review

The concern for structural safety of general cargo ships follows from the fact that during the period from 1995 to 2000 approximately 90 losses of these ships per year occurred, which in other words means one ship every 4 days, with 170 fatalities per year. Even 42% of losses of all merchant ships belong to general cargo ships and similar percentage is valid also for fatality experience. Despite these figures, general cargo ships are not considered in publicity as risky ships, probably because general cargo ship accidents are not as spectacular as for example accidents of oil tankers Erika or Prestige. An optimum structural design system for double hull oil tankers is developed based on direct calculation using the generalised slope deflection method previously proposed by the authors. For the optimization technique, the Hooks & Jeeves direct search method is applied to the minimum weight design problems with discrete design variables. A minimum weight design program is developed for the longitudinal members by the classification rules and for the transverse frames and bulkhead members by the generalized slope deflection method. Using this program, a minimum hull weight design of double hull tankers considering tank arrangement is performed and the design results are compared with existing ships. The application of composites as an alternative material for marine steel hatch covers is the subject of this study. Two separate approaches are considered; weight reduction approach and strengthening approach. For both approaches Finite Element Analysis (FEA) was performed using ANSYS software. Critical design parameters of the composite hatch cover and FEA are discussed in details. Regarding the weight reduction approach; steel hatch covers of a bulk carrier were replaced by composite covers and a weight reduction of 44.32% was achieved leading to many benefits including fuel saving, Deadweight Increment and lower center of gravity of the vessel. For the strengthening approach; the foremost hatch cover was strengthened to withstand 150% of the load required by IACS for safer navigation while no change in weight was made between the steel and composite covers. Results show that both approaches are feasible and advantageous. Results demonstrate that composite leaf spring deflection for a particular load is less compared to conventional leaf spring. Stress generated in the E-Glass/Epoxy leaf spring is lower than steel leaf spring. Composite (E-Glass/Epoxy) leaf spring directional deformation is low compared to steel leaf spring. Composite leaf spring is lighter in weight compared to conventional steel leaf spring.

## 3. Methodology of hatch cover

The application of composites as an alternative material for marine steel hatch covers is the subject of this study. Two separate approaches are considered; weight reduction approach and strengthening approach. For both approaches Finite Element Analysis (FEA) was performed using ANSYS software. The following structural analysis was performed on a typical bulk carrier, where two approaches were used to analyze and demonstrate the benefits of using marine composite hatch cover. FEM analysis has been performed using ANSYS. The selected vessel as shown below figure is a middle size bulk carrier of 82,221 tons deadweight and total cargo holds capacity of 97,186.1 m3 , The main particulars of the vessel as shown in table.

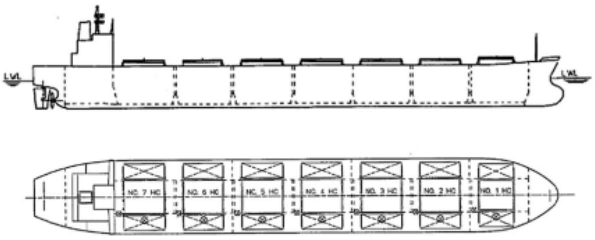

Fig 1 Arrangement of ship's cargo holds and covers

Table 1Hatch covers dimensions.

| H.C.no | length | width |
|---|---|---|
| 1 | 14,520 | 14,040 |
| 2 | 18,080 | 15,640 |
| 3 | 18,080 | 15,640 |
| 4 | 18,080 | 15,640 |
| 5 | 18,080 | 15,640 |
| 6 | 18,080 | 15,640 |
| 7 | 18,080 | 15,640 |

In this present work hatch cover number 1 has selected to run the analysis. It is having 14.5 m length 14 m width and 0.9m height. Total weight of steel hatch cover is 50.55 tons according to reference article. The load applied on the hatch cover is 101,708.949 Pa; which is 1.5 the load specified by IACS UR S21.

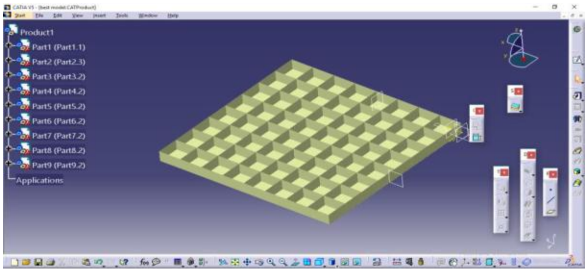

Fig 2 3D model of hatch cover

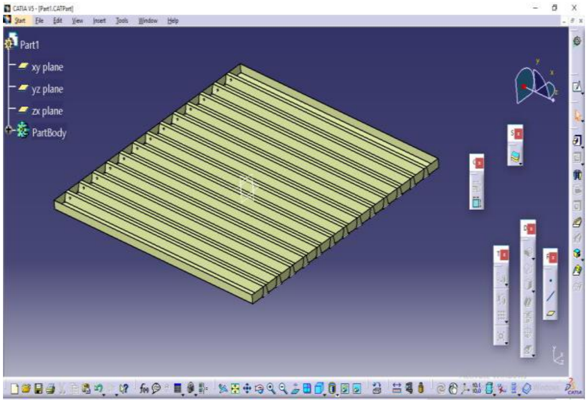

Fig 3 optimized 3d model in CATIA.

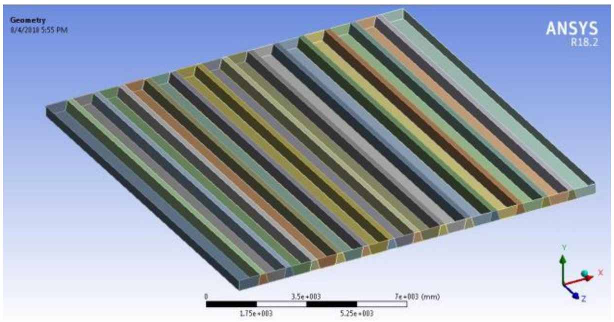

Fig 4 optimized geometry model imported into ansys.

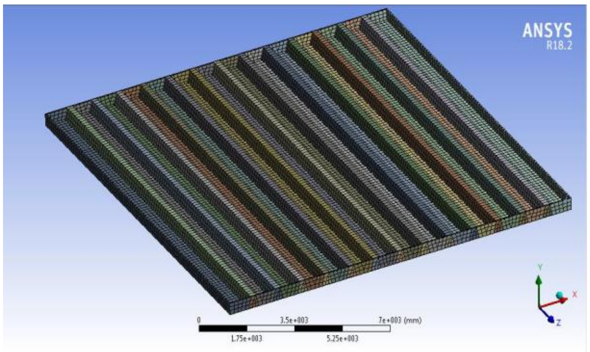

Fig 5 finite element model of optimized geometry

Generally mesh 200 element is available in the ANSYS workbench. These elements are used to solve in the shell and solid element. When there is number of element present we can get the exact results. At the same time, hexagonal meshing gives best results. In the present work, the entire assembly components are divided into 203276 tetrahedron elements and 50261 nodes.

## 4. Analysis

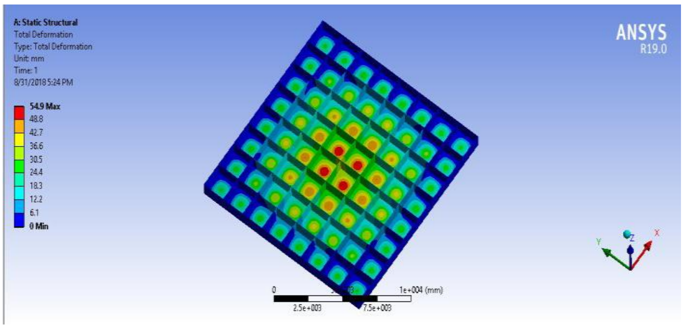

Fig 6 total deformation of steel hatch cover

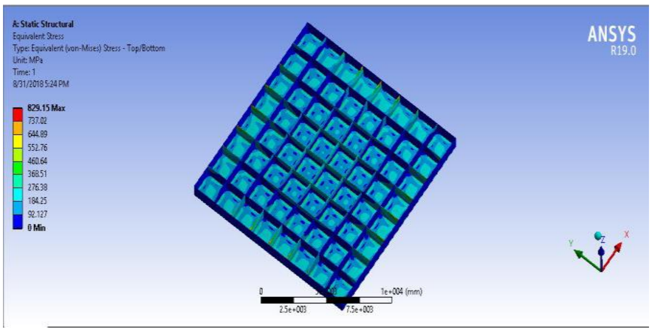

Fig 7 stress of steel hatch cover

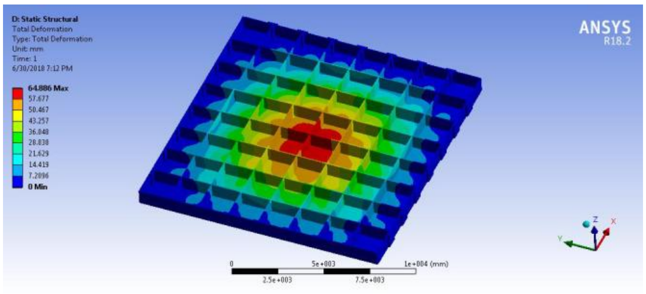

Fig 8 total deformation of E-Glass hatch cover.

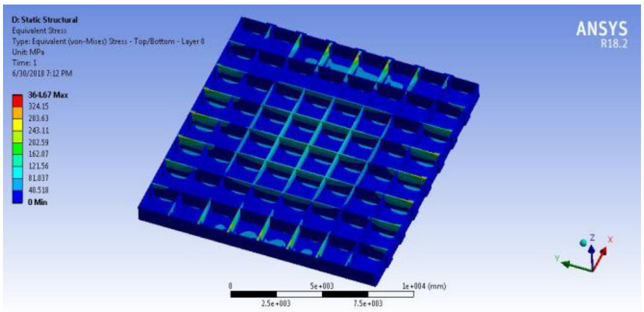

Fig 9 stress of E-Glass hatch cover.

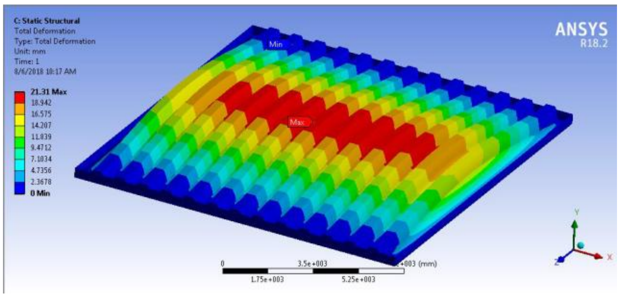

Fig 10 total deformation of E-Glass optimized hatch cover

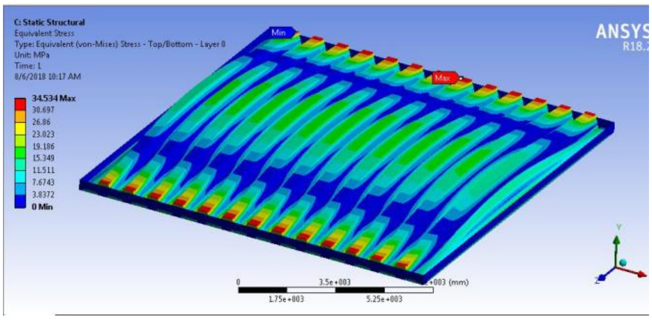

Fig 11 stress of E-Glass hatch cover

## 5. Genetic algorithm

The starting population is repeated to calculate the fittest solution as explained in following steps.

Step 1: [Start] randomly generate population of n chromosomes as per population size.

Step 2: [Fitness] Evaluate the fitness f(x) of each chromosome x in the population.

Step 3: [New population] Create new population by repeating following steps until the new population is complete.

[Selection] Select two parent chromosomes from a population.

[Crossover] With a crossover probability, crossover the parents to form a new offspring. If no crossover was performed, offspring is the exact copy of parents.

[Mutation] With a mutation probability, mutate new offspring at each locus.

[Accepting] place new offspring in the new population.

Step 4: [Replace] Use new generated population for a future run of the algorithm.

Step 5: [Test] if the end condition is satisfied, stop, and return the best solution in current population.

Step 6: [Loop] Go to step 2 Step 7: [Stop] Stop when the fittest value is obtained. We are using those basic steps for finding the optimal resources for an organization in Medium range prospective using MATLAB software package.

### *5.1 Genetic Algorithm Flow chart*

### Genetic Algorithm Approach

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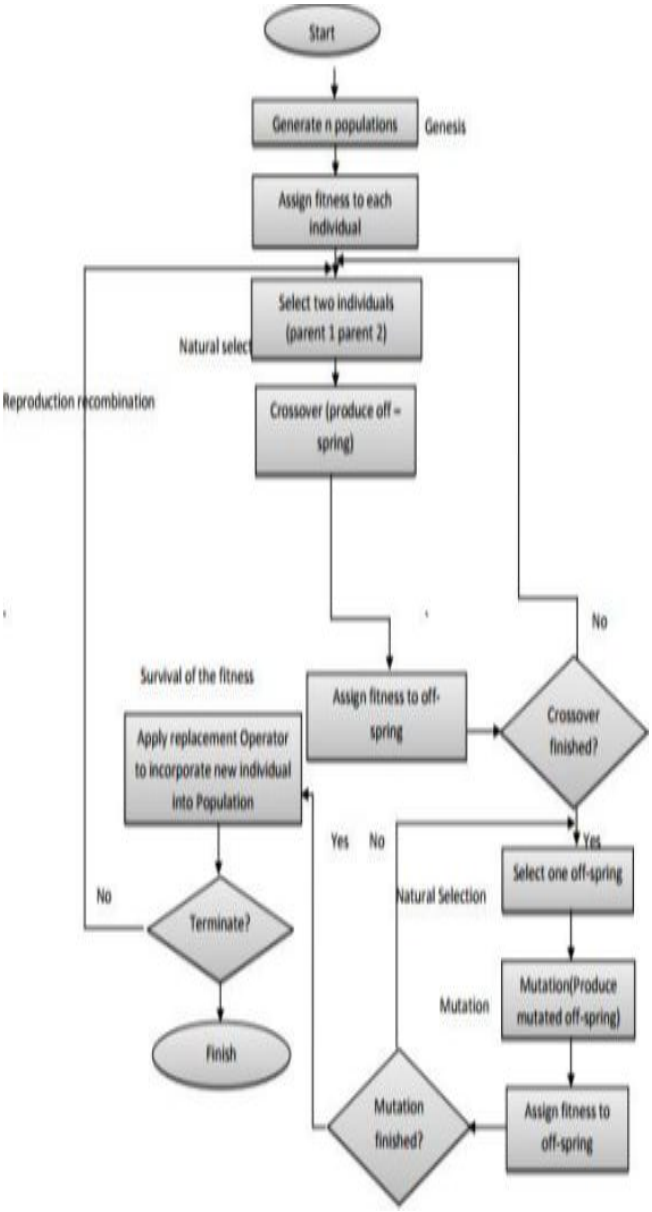
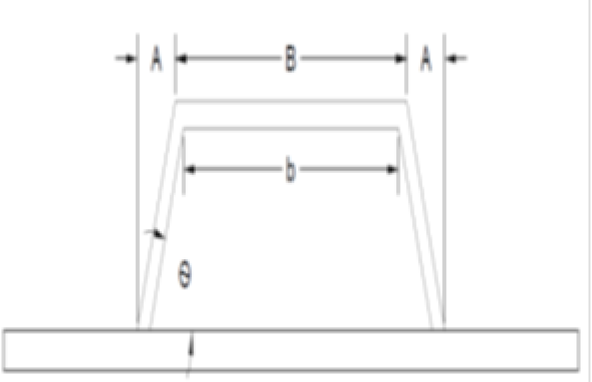


Fig 12 Hat section profile



### 5.2 Objective Function:

Minimize the Weight= $\rho pxLxWxtp + \rho s(2xAxcos\theta - 1 + B)xNxts$

Where

$\rho p$ =density of base plate.
L=length oh hatch cover.
W=width of hatch cover.
$tp$= thickness of base cover.
$\rho s$=density of stiffener.
A=stiffener slat width.
B=middle width of stiffener.
N=number of stiffeners.
$ts$=thickness of stiffener.

Constraints:
N x B≤ 14.04-----------------(1)
D≤0.9--------------------------(2)
Deformation constraint
(0.0069/ (BD^3-bd^3) ≤δ—(3)
Stress constraint
(15812280xD)/( BD^3-bd^3) ≤σ---(4)
B=a(1);D=a(2);b=a(3);d=a(4);N=a(5); σ=a(6); δ=a(7);t=a(8);L=a(9).

Weight of the composite hatch cover using GA= 31 tones.

Actual Weight of hatch cover= 52 tones

Percentage of Weight Reduction
={(Actual weight-weight obtained using GA)/( Actual weight)} ×100
={(52 -31)/ 52 }×100
=40%

### 5.3 Model analysis

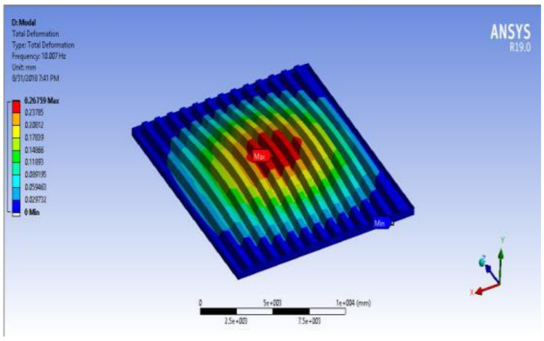


Fig 13 1st mode of E-Glass hatch cover

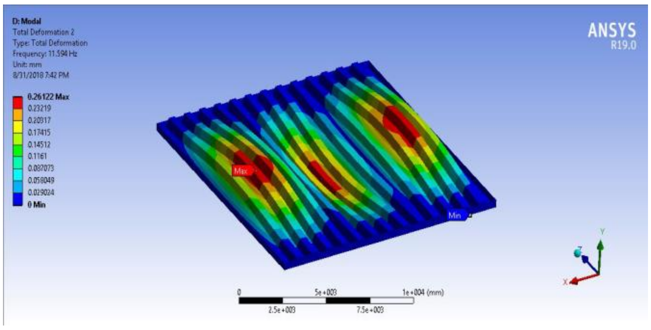


Fig 14 2nd mode of E-Glass hatch cover

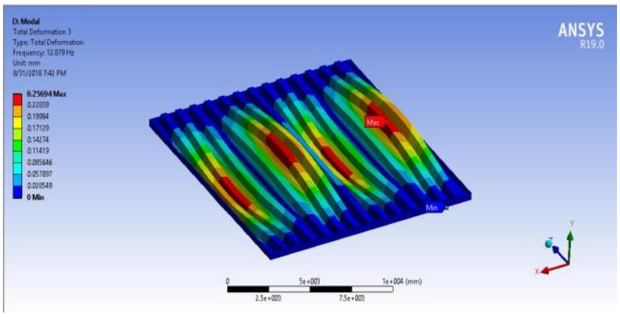


Fig 15 3rd mode of E-Glass hatch cover.

## 6. Results and discussion

Table 2 results of original model hatch cover.

| Material | Weight | Displacement | Stress |
|---|---|---|---|
| Steel | 52 | 54.9 | 829 |
| Glass | 50 | 64.8 | 364 |
| Carbon | 38 | 35.5 | 547.5 |
| Kevlar | 35.8 | 30.6 | 378.9 |

Table 3 displacement results of both models

| Material | Original model | Optimized model |
|---|---|---|
| Glass | 64.8 | 21.31 |
| Carbon | 35.5 | 11.6 |
| Kevlar | 30.6 | 12.25 |

Table 4 stress results of both models

| Material | Original model | Optimized model |
|---|---|---|
| Glass | 364 | 34.53 |
| Carbon | 547.5 | 48.22 |
| Kevlar | 378.9 | 54.04 |

Table 5 natural frequencies of optimized hatch cover

| Mode no | Glass | Carbon | Kevlar |
|---|---|---|---|
| 1 | 10 | 15.6 | 17.2 |
| 2 | 11.594 | 17.85 | 19.1 |
| 3 | 12.879 | 19.68 | 22.2 |
| 4 | 14.35 | 21.8 | 24.1 |
| 5 | 15.96 | 24.14 | 26.3 |

Table 6 Buckling analysis results of optimized hatch cover

| Material | Glass | Carbon | Kevlar |
|---|---|---|---|
| Buckling strength in m.pa | 2.8 | 3.4 | 5 |

## 7. Conclusion

In this study, one of methods for lightening the ship weight based on the optimization technique was proposed. Especially, This study focused on a hatch cover which is one of core parts in a B/C, and thus the hatch cover of the bulk carrier was selected as an optimization target. For this, an optimization problem in order to determine optimal principal dimensions of the hatch cover was first formulated. To solve this optimization problem, genetic algorithm in mat lab code is used. the result shows that the optimization technique can decrease the hatch cover's weight by about 40%. If the optimization is applied to all hatch covers, the reduction ratio of the weight will be Increased. Thus, this study will be able to contribute to make energy saving and environment-friendly ship in shipyard. Same dimensional parameters are considered to run the structural analysis. Deformation and stress stresses are reduced as compared to original model. vibration analysis is performed to check the resonance behavior for running condition.

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