WEIGHT REDUCTION AND STRENGTHENING OF MARINE HATCH COVERS BY USING COMPOSITE MATERIALS

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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.

Keywords: Hatch cover, Bulk carrier, Optimization technique, Genetic algorithm, Structural behavior.

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. Cargo holds are box shaped to fit containers and some holds can be equipped with tween decks to improve flexibility of cargo mixture in same hold. Holds are typically equipped with dehumidifier for sensitive cargo. 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.

A large steel structure fitted over a hatch opening to prevent the ingress of water into the cargo hold. It may also be the supporting structure for deck cargo. Various designs exist for particular applications. The hatch cover has to be weatherproof and has to remain so when conditions change as a result of waves, temperature and cargo.

1.1 Classification:

Hatch covers of ships are designed to be efficient and cost effective, as an initial investment and during service, and at the same time should suit the demands of the various types of cargo vessels. The major objective of hatch covers and coamings on ships is to prevent the ingress of water into the cargo hold and protect the goods from being damped and damaged.

Hatch covers also act as a barrier to the ship's internal structure by enduring the green water loads in extreme weather, which can damage the internal structure of ship due to corrosion.

The various types or hatch covers that are mainly used on board are as follows

1.1.1Folding hatch covers

Folding hatch covers for weather decks can be either of the low or high stowing type. The low stowing version and single pull hatch covers are designed in a number of panel configurations. The high stowing versions are also available in a number of configurations: for example, with two to six panels and with stowing taking place at one or both ends of a hatch.

Fig1.2: **Folding hatch covers**

1.1.2 Lift-and-roll Piggy-Back covers

One panel of each pair is operated by high-lifting hydraulic cylinders for vertical movement. The horizontal movement of the other panel is achieved by traction drive via electric motor, planetary gear and hydraulic brake after it has been raised by a wheel-lifting device.

Fig 1.3: **Piggy-Back covers**

1.1.3 Lift-away hatch covers

Usually multi-panel units designed so that there are several panels for each hatch opening. They can be opened in an independent order and they allow partial hatch opening. Hatches are opened with a spreader using the vessel cranes or container cranes on shore. After removal, the panels can be stowed on top of adjacent covers which are placed on the quay or on the ship deck. The weight of the cover, and any cargo stowed on it, is transferred to the ship structure by bearing pads.

Fig 1.4: **Lift-away hatch covers**

1.1.4 Pontoon hatch covers

Pontoon type hatch covers feature a flat top and flat bottom plate and are weathertight.

Fig 1.5: **Pontoon hatch covers**

1.1.5 Rolling hatch covers

Rolling covers are divided into two main types considering opening direction. Side-rolling covers open sideways and end-rolling covers lengthwise. Both types are well suited to act as weather deck covers for dry bulk carrier and, when designed to sustain internal liquid loads, also for OBO and Ore/Oil ships.

Fig 1.6: **Rolling hatch covers.**

2. LITERATURE REVIEW

The term “general (multipurpose) cargo ships” covers many different ship designs that do not fi t into other more specialized cargo ship types. Thus, general cargo ships are not specialized for transport of only dry bulks, only containers or only heavy-lift cargoes, but they have flexibility to carry any of these cargo types. General cargo ships are the world’s most numerous ship types, excepting fishing vessels. Thus, in the year 2002 their share in the overall world merchant fleet amounted to about 37% in numbers and to about 11% in dwt [1].

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 fi gures, 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 [2].

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.

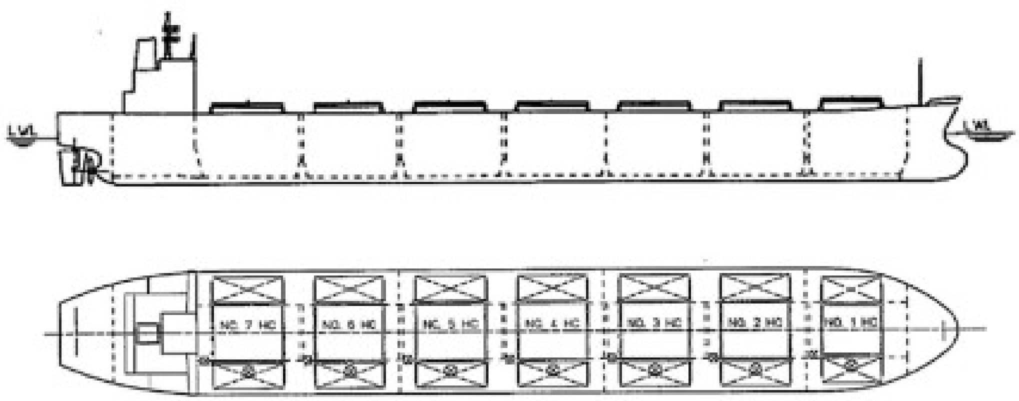


Fig 3.2: Arrangement of ship's cargo holds and covers.

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

Table 3.1: Hatch covers dimensions.

4. COMPUTER AIDED MODELING

Throughout the history of our industrial society, many inventions have been patented and whole new technologies have evolved. Perhaps the single development that has impacted manufacturing more quickly and significantly than any previous technology is the digital computer. Computers are being used increasingly for both design and detailing of engineering components in the drawing office.Computer-aided design(CAD) is defined as the application of computers and graphics software to aid or enhance the product design from conceptualization to documentation. CAD is most commonly system to support the engineering design.

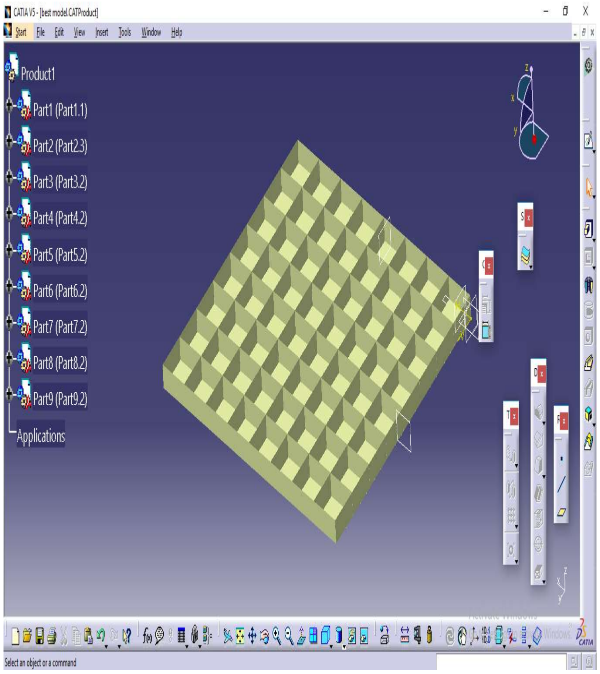


Fig 4.1: 3D model of hatch cover.

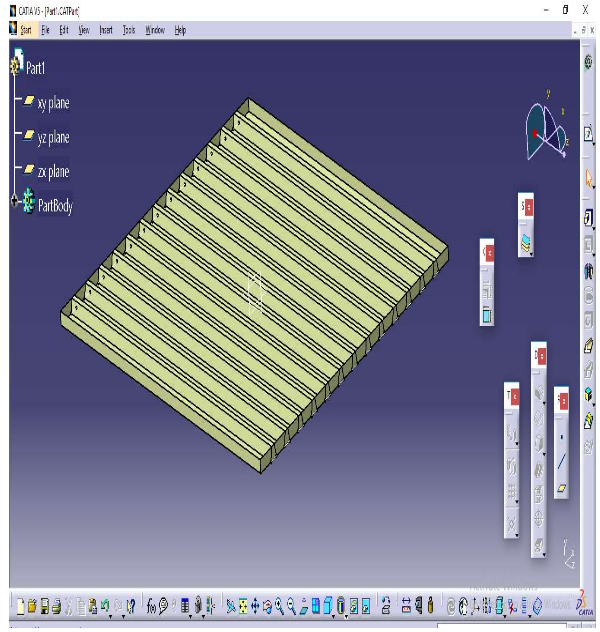


Fig 4.2: optimized 3d model in CATIA.

5. FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) was developed by R. Courant in 1943, he applied minimization of variation calculus and Ritz method of numerical analysis to procure exact solutions to vibration systems. Later, in 1956, H. C. Martin, R. W. Clough, L. J. Topp and M. J. Turner published an article by, established a broader definition of numerical analysis. This article focused on the “deviation and stiffness of complex structures".

During 70's, Finite Element Analysis was so expensive that it was used in mainframe computers which are owned by the aeronautics, automotive, military, and nuclear industries. Since there was fast decrease in the rate of computers and the astounding use of computing power, Finite Element Analysis was formed so accurate. The modern days supercomputers are now capable of producing accurate results for all kinds of parameters.

The Finite element is a mathematical method for solving ordinary and partial differential equations. Finite element method is a numerical method to find a exact solution to the boundary value which are defined in the differential equation form. And these elements are subdivided into, smaller and simpler parts. In virtually all fields of study of the natural objects, the applications of the Finite element method are boundless as regards the result of practical Design problems.

Due to the low cost of computing power in recent years, Finite Element Analysis has a record of being used to interpret complex and cost pivoted problems. Traditional methods solely cannot provide sufficient information to choose the safe working limits of a leading civil engineering construction or an Automobile or a Nuclear reactor that are failed in the economic and social costs that would be undesirably high.

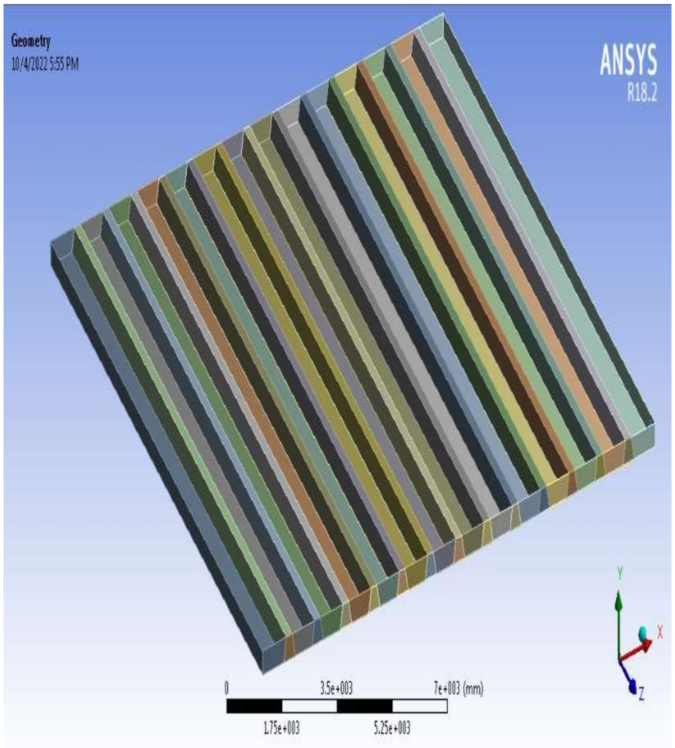


Fig 5.1: optimized geometry model imported into ansys.

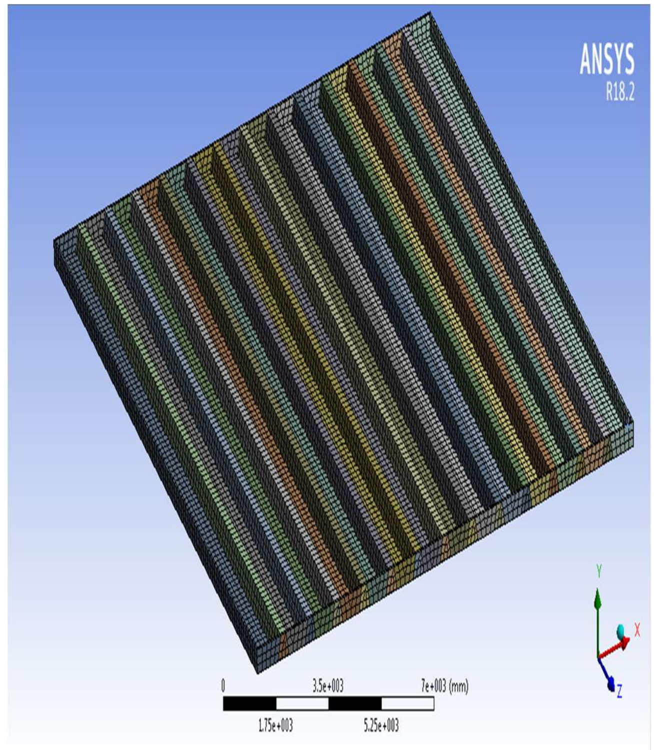


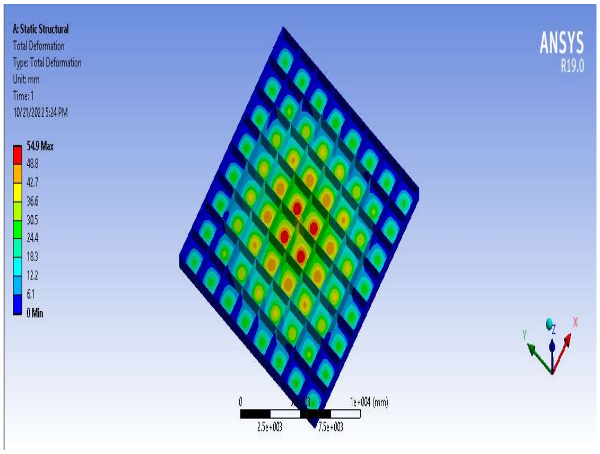
Fig 5.2: finite element model of optimized geometry.

Post possessing is output of analysis. After we solved the problems, to check the results postprocessor is used. In this we can find in different direction for deformation, strains and stresses. And this can be converted into an image and we can paste it in the report.

In this present work, initially we took different geometric parameters are taken form existing hatch cover for that to provide a weight reduction, in stiffener assembly small modification is created. In this whole assembly, using detailing drawings we created in CATIA software. The Individual parts is previously created and these parts are joined together we created assembly part using CATIA software and saved as IGS Software in particular location of the computer.

To run the Analysis, 64 bit operating system, 4GB ram And ANSYS 19.0 is used. Without any problem, to run analysis software this configuration is very apt. The previously created IGS file is imported on ANSYS file geometry. In ANSYS, static structure analysis is performed. The table which is shown below, different materials for different components are used hatch cover assembly. Solid mesh 200 element are used to divide the geometric body in to small strips (Finite elements)

In the present work, the entire assembly components are divided into 203276 tetrahedron elements and 50261 nodes. In real time, the position where we place the hatch cover in its exact location, likewise in ANSYS software same location we applied the boundary condition. Fixed boundary conditions are applied at side supports of hatch cover. Bounded connection is provided between stiffeners and base wall component. Load applied on top face of hatch cover. Here 0.1M.Pa loading s applied on the hatch cover.



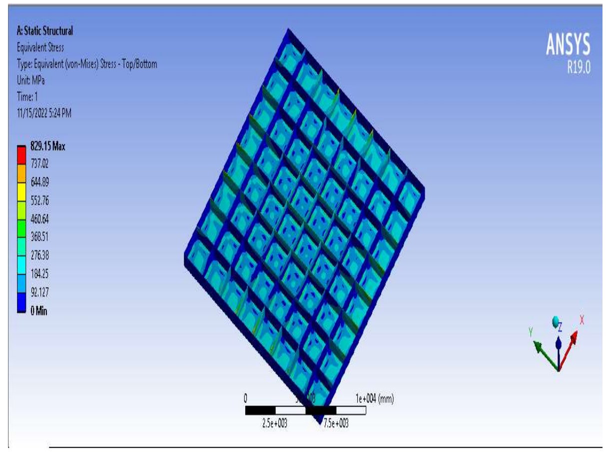
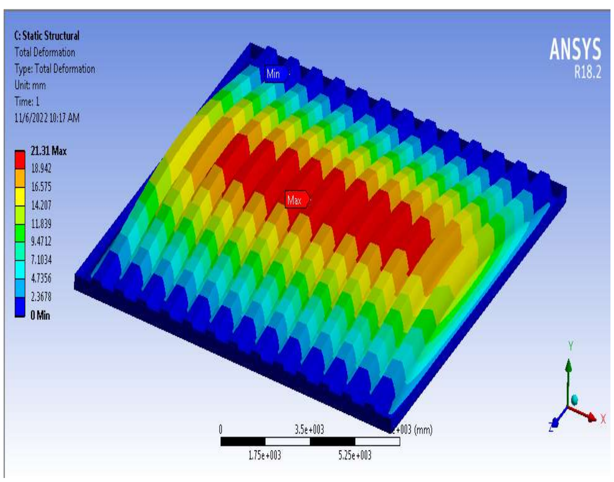


fig5.3: total deformation of steel hatch cover. Fig 5.4: stress of steel hatch cover.

In the above image shows the total deformation of hatch cover after 0.1 M.Pa applied on top cover and the red indicate the maximum deformation and blue indicates minimum deformation. Maximum deformation occurs at the middle of the hatch cover because there is no support at the middle, so there is a high chance of the seat to get bent. Minimum deformation appears at the hook of the supports of wall. All together maximum deformation is 64 mm. This deformation is much of considerable deformation.



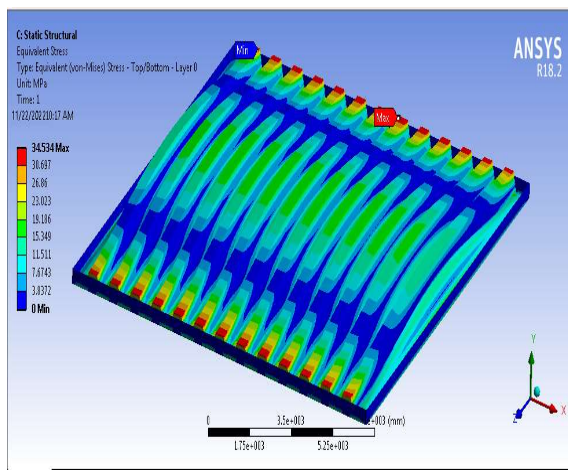


Fig5.7: total deformation of E-Glass optimized hatch cover. Fig 5.8: stress of E-Glass hatch cover.

In the above image shows the von mises stress of hatch cover after 0.1 M.Pa applied on top cover and the red indicate the maximum deformation and blue indicates minimum deformation. Maximum deformation occurs at the middle of the hatch cover because there is no support at the middle, so there is a high chance of the seat to get bent. Minimum deformation appears at the hook of the supports of wall. All together maximum stress is 34.5 MPa.

6. GENETIC ALGORITHM

High computational cost has been a major impediment to the widespread use of evolutionary algorithms in industry. While the clock time for optimization using the GA can be reduced by parallelization, the computational cost can only be improved by reducing the number of function evaluations. For single objective optimization problems, the convergence curve can be utilized to obtain a suitable compromise between the computational cost and the quality of the solution. A non-domination criterion based metric that tracks the growth of an archive of non-dominated solutions over a few generations is proposed to generate a convergence curve for multi-objective evolutionary algorithms. Two analytical and two crashworthiness optimization problems were used to demonstrate the practical utility of this measure. It was observed that, similar to single-objective optimization problems, there were significant advances towards the POF in the early phase of evolution and relatively smaller improvements were obtained as the population matured. This information was used to terminate the search to obtain a good trade-off between the computational cost and the quality of the solutions. The paper also demonstrates the successful use of compute clusters for parallel processing to significantly reduce the clock time for optimization.

Genetic algorithms (GAs) have been demonstrated to efficiently solve multi-objective optimization problems because they result in a diverse set of trade-off solutions in a single simulation run. However, the GA requires tens of thousands of simulations to converge to the global Pareto optimal front. Though a recent study highlighted the application of a multi- objective GA with a small number of simulations, the high computational cost remains the biggest potential drawback for solving engineering problems that may involve impact or other expensive simulations to analyze the problem. The continual reduction in the cost of the hardware, the clusters of processors have become increasingly common. Such systems are particularly useful for running genetic algorithms that are inherently suited to parallelization. One can reduce the clock time significantly by concurrently running many individuals in a GA population. The time to analyze each design can be reduced further if the analysis code can utilize multiple processors as for instance is the case with the MPP version of LSDYNAR used in this study. While this two level parallelization has a multiplicative effect on the clock time-savings, the ever-increasing complexity of computational models may easily offset the potential gains of parallelization.

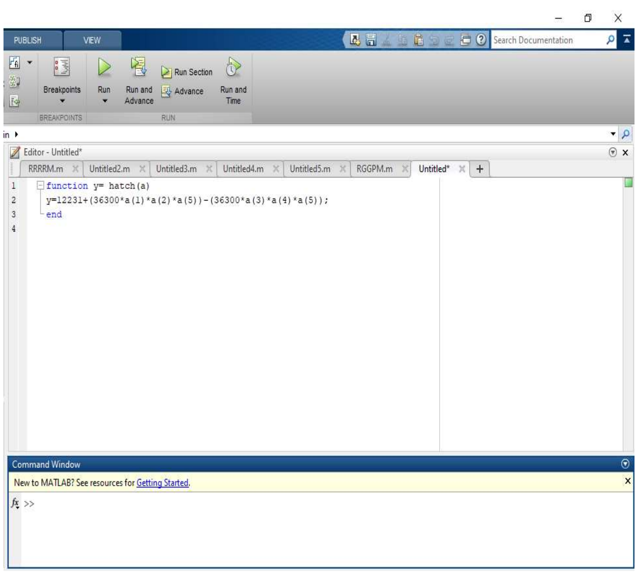


Fig.6.1 Objective function window.

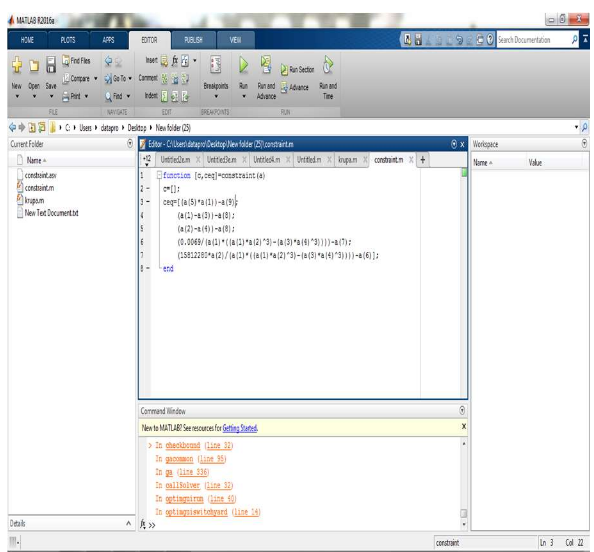


Fig.6.3 Constraint function window.

Result was obtained by the MATLAB optimization tool. In that GA single objective tool is used to minimize the total weight of the problem. The window of optimization tool is given in Figure. 3. The 9 variables are tabulated in Table. 4. The total weight is minimized and the maintain the deformation and stress constrains. The final answer after optimization is shown by GA optimization tool.

GENETIC ALGORITHM CODING In MATLAB the objective function and constraint function was saved as m file for to use in GA optimization tool because optimization tool requires the objective function and the constraint function in m file.

7. MODEL ANALYSIS

Any physical system can vibrate. The frequencies at which vibration naturally occurs, and the modal shapes which the vibrating system assumes are properties of the system, and can be determined analytically using Modal Analysis.

Modal analysis is the procedure of determining a structure's dynamic characteristics; namely, resonant frequencies, damping values, and the associated pattern of structural deformation called mode shapes. It also can be a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a spectrum analysis.

Modal analysis in the ANSYS family of products is a linear analysis. Any nonlinearities, such as plasticity and contact (gap) elements, are ignored even if they are defined. Modal analysis can be done through several mode extraction methods: subspace, Block Lanczos, Power Dynamics, Reduced, Unsymmetrical and Damped. The damped method allows you to include damping in the structur

7.1 USES OF MODAL ANALYSIS

Modal analysis is used to determine the natural frequencies and mode shapes of a structure. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions. They are also required to do a spectrum analysis or a mode superposition harmonic or transient analysis. Another useful feature is modal cyclic symmetry, which allows reviewing the mode shapes of a cyclically symmetric structure by modeling just a sector of it.

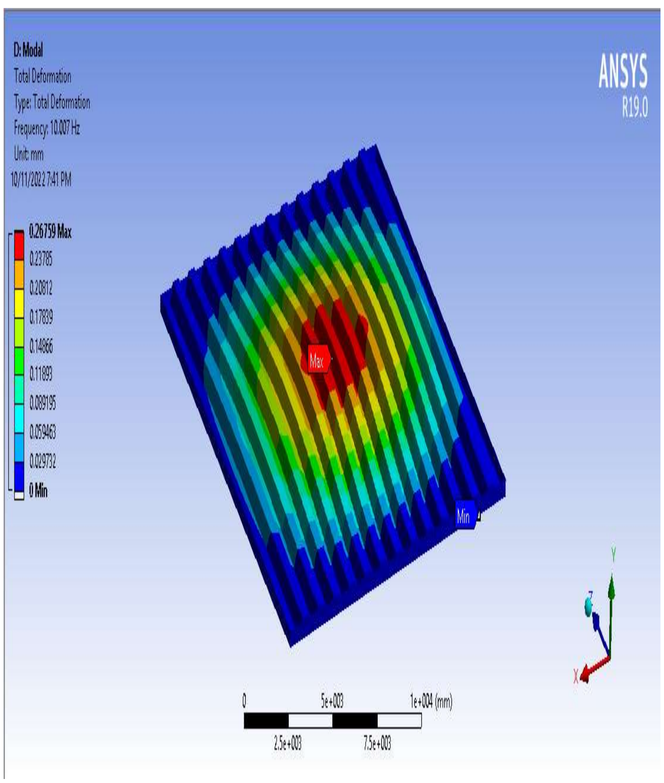


Fig 7.1: 1st mode of E-Glass hatch cover.

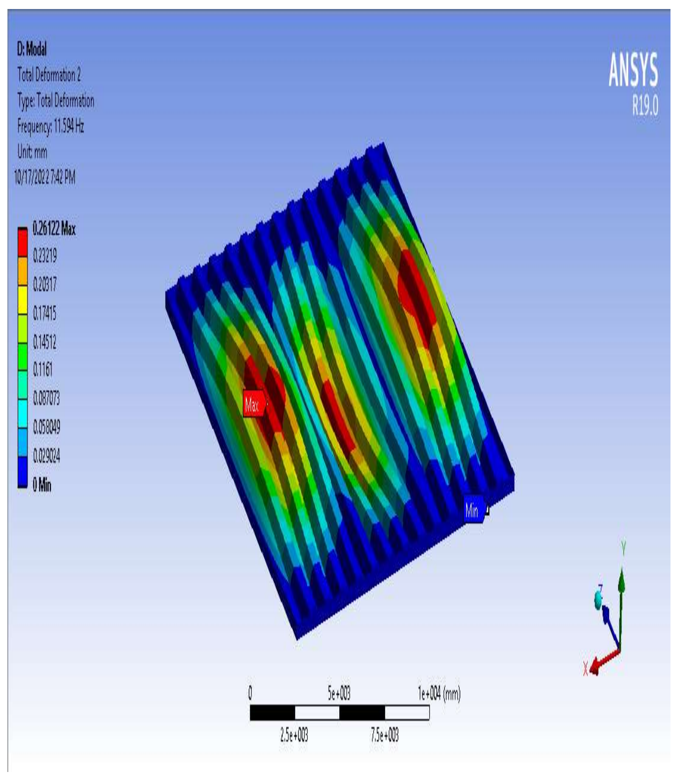


Fig 7.2: 2nd mode of E-Glass hatch cover.

This mode shape can be determined by Eigen value of vibration equation like single or two degree of freedom system. Here mode shape at 2nd frequency is expanding towards the height of hatch cover. and 2nd natural frequency 11.5 HZ. Double wave Bending motion is observed at center portion.

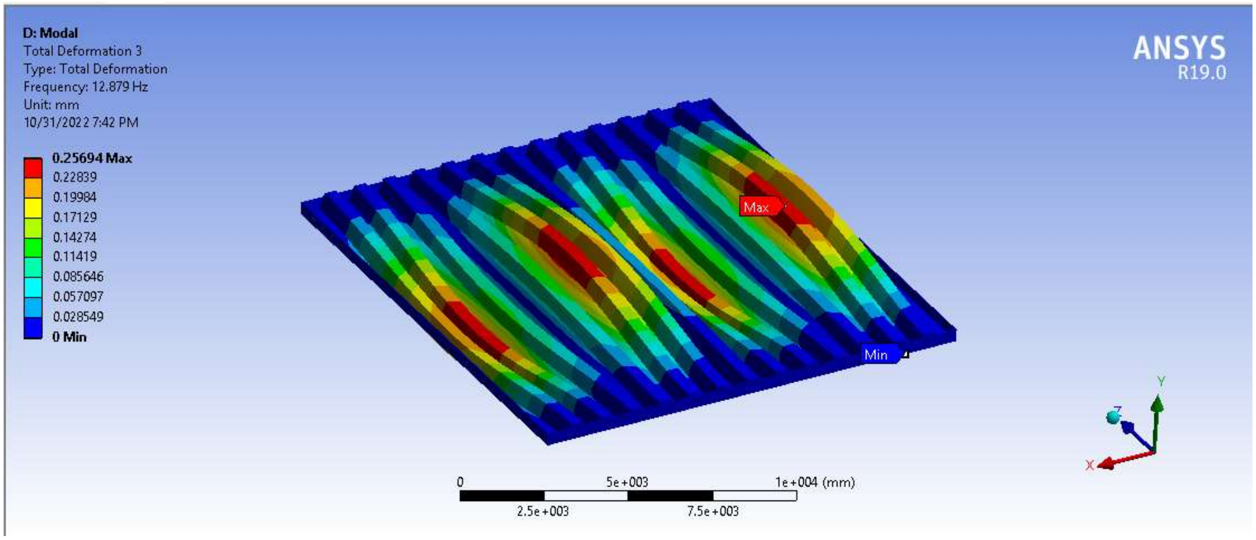


Fig 7.3: 3rd mode of E-Glass hatch cover.

This mode shape can be determined by Eigen value of vibration equation like single or two degree of freedom system. Here mode shape at 3rd frequency is expanding towards the height of hatch cover. and 3rd natural frequency 12 HZ. Double wave Bending motion is observed at center portion.

8. RESULTS AND DISCUSSION

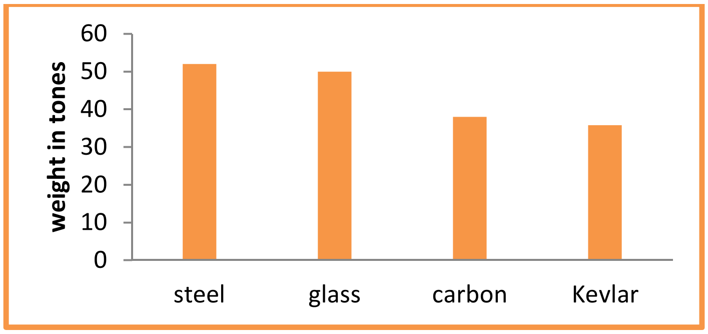
In this study computer aided design, finite element analysis and vibrations are the tools which have been used. The analysis of a cargo ship hatch cover has been performed using the Finite Element technique. It simulates the behavior of the hatch cover under its working load conditions. CATIA has been used to develop a three dimensional geometrical model. The hatch cover has been loaded with static load cases which represent the working load conditions. Maximum and minimum stresses were noted and a comparison has done with different materials.

In this present work the structural and vibration analysis of hatch cover for four different materials, loading and boundary condition are taken as real condition and the results are shown below.

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

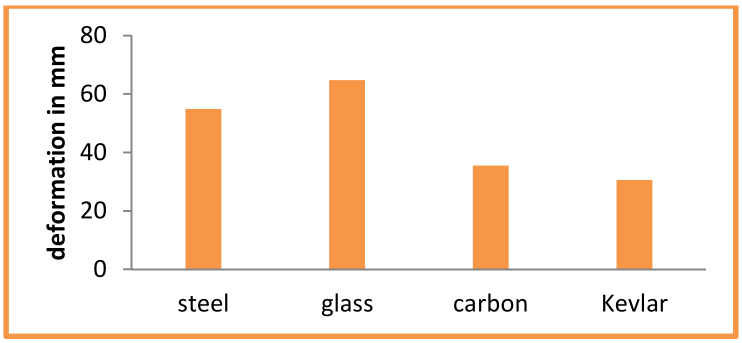
Table 8.1: results of original model hatch cover.

The above table shows the weight, displacement and stress of hatch cover at different materials.



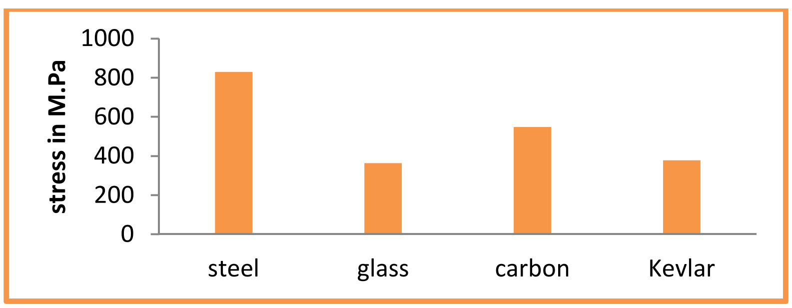
Graph 8.1: weight comparison of original model hatch cover

The above graph shows the weight comparison for different materials. Here steel material having heavy weight like 52 tons as compared to remaining materials. Kevlar material having minimum weight as compared to steel and other materials.



Graph 8.2: displacement comparison of original model hatch cover.

The above graph shows the displacement comparison for different materials. Here glass material having maximum deformation 64.8mm as compared to remaining materials. Kevlar material having minimum displacement 30.6 mm as compared to steel and other materials.



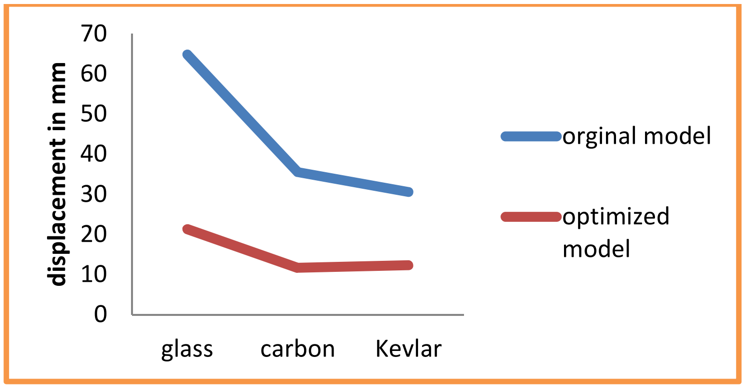
Graph 8.3: stress comparison of original model hatch cover

The above graph shows the stress comparison for different materials. Here steel material having maximum stress 829 M.Pa as compared to remaining materials. Glass material having minimum stress 364 M.Pa as compared to steel and other materials.

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

Table 8.2: displacement results of both models.

The above table shows the deformation results for original and optimized model of hatch cover. Here all dimensions are noted in millimeters.

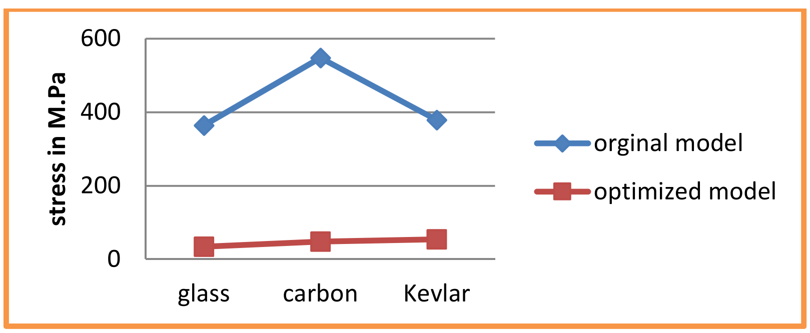


Graph 8.4: displacement results of both models.

The above graph shows the displacement comparison for two models. Here original model of hatch cover having maximum deformation as compared to optimized model of hatch cover. Kevlar material having minimum displacement as compared to steel and other materials.

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

Table 8.3: stress results of both models.

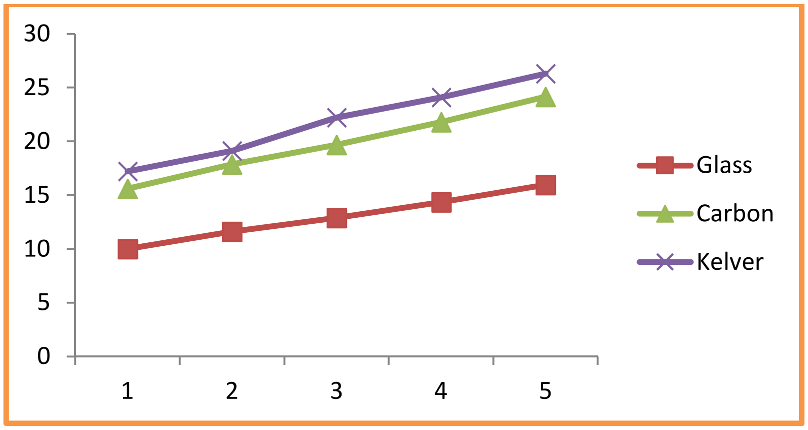


Graph 8.5: stress results of both models.

The above graph shows the stress comparison for two models. Here original model of hatch cover having maximum deformation as compared to optimized model of hatch cover. Glass epoxy material having minimum stress as compared to steel and other materials.

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 8.4: natural frequencies of optimized hatch cover.

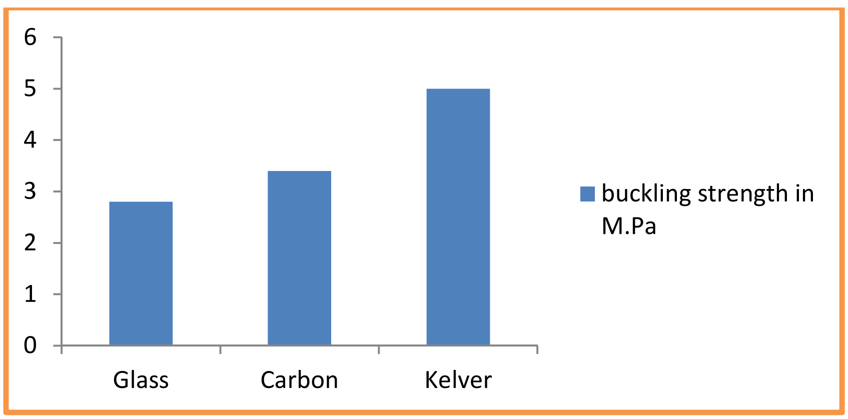


Graph 8.6: natural frequencies of optimized hatch cover.

The above graph shows the natural frequencies of different materials of optimized hatch cover. Kevlar materials are having maximum natural frequencies as compared to reaming materials.

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

Table 8.5: Buckling analysis results of optimized hatch cover.



Graph 8.7: Buckling analysis results of optimized hatch cover.

The above graph shows the buckling strength of optimized hatch cover. here glass material are having minimum critical strength as compared to reaming materials. And Kevlar material having maximum critical strength.

9.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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