Structural Analysis of Dyneema-Epoxy Based Hovercraft Hull Using Finite Element Method

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Abstract: In the present scenario for hovercrafts, Aluminium alloys and balsa wood are used as Hull materials. It is a prerequisite that the hull material should possess lower density, high strength to weight ratio, resistance to corrosion and abrasion. Developments in the field of composites have unearthed new materials such as Carbon Fiber, Zylon, Kevlar, Dyneema etc. which suit the requirements of the hull material. In this paper Dyneema-Epoxy composite material is used as the hull material and also changes are made to the structure of the hull in order to decrease the weight of the hull, thereby decreasing the lift power required, increasing the weight carrying capacity and allowing better distribution of stresses. The displacement and stress characteristics of the hovercraft using this composite are studied and compared with those of the earlier hull materials. This research paper comprehensively deals with the evolution and working of air cushion vehicles, modifications made to the structure and an analysis of the corresponding results. The tools used are CATIA for 3D modelling and Hypermesh for analysis.

Keywords: Trapped air, Strength to Weight ratio, Hull, Composite material

I. INTRODUCTION:

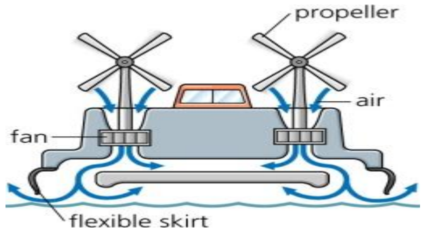
Hovercraft is a hybrid vehicle, simple, versatile and go anywhere type. It can operate along weed and reed filled waterways where propeller driven boats would become fouled, and over short stretches of land or in water that is simply too shallow for other boats. In places where the water is too difficult for a boat or the ground too soft for a truck, a hovercraft may be perfect. A hovercraft, also known as an air-cushion vehicle or ACV, is a craft capable of travelling over land, water, mud or ice and other surfaces both at speed and when stationary **[1]**. Hovercrafts are hybrid vessels operated by a pilot as an aircraft rather than a captain as a marine vessel.

The objective of this paper is to study Dyneema-Epoxy hovercraft hull with different wall thickness. Also changes are made to the design of the existing hull by decreasing the thickness and then using rectangular support bars of various thicknesses for reinforcement. The thickness of the hull is decreased with increase in the number of support bars. The corresponding designs are analyzed and optimal values are selected.

II. BASIC PRINCIPLEOFOVERCRAFT :

Hovercraft use blowers to produce a large volume of air below the hull that is slightly above atmospheric pressure. The pressure difference between the higher pressure air below the hull and lower pressure ambient air above it produces lift, which causes the hull to float above the running surface. A hovercraft has one or more blowers that blow air underneath the craft, which is contained by a skirt. The skirt that is around the perimeter of the hovercraft performs an extremely important function in containing the air cushion. By using a skirt, the amount of engine power required to lift the craft is considerably reduced and as an added benefit, extra hull surface clearance is obtained. The skirt is a long strip of material that is mounted onto the underside of the craft. When the skirt is inflated, it lifts the hovercraft. The escaping air coming from where the skirt touches the ground creates a friction-less cushion of air. Because the hovercraft has practically no friction, it takes little force to move the craft **[2]** . For stability reasons, the air is typically blown through slots or holes around the outside of a disk or oval shaped platform, giving most hovercraft a characteristic rounded rectangle shape. Typically this cushion is contained within a flexible "skirt", which allows the vehicle to travel over small obstructions without damage.

The Fig.1. Elucidates the important components of the Hovercraft namely Hull, Lift system, Thrust system, Skirt Steering systems **[3]** and also shows the basic principle of a hovercraft **[4].** Air is directed underneath the craft by a blower, and the air that escapes out of the flexible skirt creates a near frictionless environment which enables the craft to hover. The craft can move forward and turn by using propellers to propel the craft **[5].**



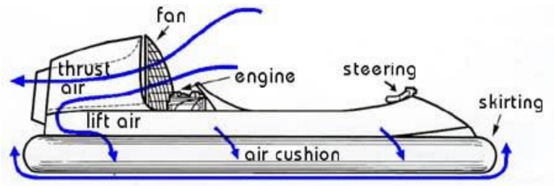


Fig .1. Components and Principle of Hovercraft

III. MATERIAL SELECTION:

Wood is a popular choice for hovercraft construction, but its construction quality depends on the skill of the constructor. It can be heavy if the wrong grades are chosen and will rot in time. The next popular choice is Aluminium, but it tends to be heavy and expensive. Glass reinforced plastic (GRP) is the most common hull material for professionally built hovercrafts. However its disadvantages are that it needs a mould, lots of space and some skill. They are also heavy, expensive and labour intensive. The above materials used are not as robust and repairable as they should be. Improvements can also be made to reduce the thickness of hull and reduce the weight of the hovercraft which will improve its overall efficiency. However no significant improvements are being made in this direction so far. In order to overcome the limitations of the existing system, a detailed study is conducted in the field of material science and design to find a suitable material. Composite is a unique material due to the mechanical properties of each composite. The properties of a composite varies depending on the material used, thickness or the layout of the fibers [4]. Dyneema-Epoxy composite (7: 3 by volume) is found to overcome most of the above mentioned problems. It possesses characteristics like very high tensile strength, stiffness, low density, resistance to corrosion, abrasion and had a good strength to weight ratio. It is impervious to salt water, maintains its ballistic integrity, is 40% lighter than aramids and it floats and doesn't absorb water like other aramids and glass fiber. Hence it serves as the best choice for the construction of Air Cushion Vehicles. So through this project propose to use Dyneema Epoxy as the construction material. Different orientations of Dyneema Epoxy are being studied and the orientation which produces the optimum result will be selected as the best choice.

Table .1. Comparison of properties of Aluminium, Balsa wood and Dyneema

S.No	Property	Balsa Wood	Aluminium	Dyneema(UHMWPE)
1	Tensile strength (M Pa)	75	310	3600
2	Compressive Strength(M Pa)	27		100
3	Density (g/cc)	0 .160	2.7	0.97
4	Young's modulus(G Pa)	6	70	110
5	Yield strength (M Pa)	25	386	2400
6	Poisson ratio	0.009	0.35	0.45
7	Water absorption rate	High	Low	0 %

There is no question that advanced composites are going to become more important to the marine industry. The advanced composites material systems tend to be greener than general composites, and they produce less emission in the manufacturing process. In fact, composite technology allows hovercraft makers to reduce weight and increase fuel efficiency in many types of structures. Composites are really coming of age now because there is a need for humanity to reduce the mass of material that is used to build things. Composites are used as a structural material in a wide variety of applications **[6].** The boat building industry was a pioneer in the use of these materials: the first product built using modern composites was a boat built in the 1930s, and in the 1960s the marine market was the largest user. Of these materials Today, boat builders have been building fiberglass boats for decades; more recently, builders of high-performance boats are using advanced composites (which use high-modulus/high-strength fibers with an advanced resin system, compared to general composites that use glass fiber **[7]** and polyester resin). In addition to the marine industry, composites are used for: commercial, private and military aircraft (including components for aerospace and related applications); automotive/transportation. Table.1 given below shows different factors considered important in choosing deck material and comparing the properties of traditional deck material Balsa wood, Aluminum and Dyneema fiber. The structure of Dyneema fiber shown below in the Fig.2. A clear look into the data in table 1 reveals that Dyneema would be the best choice for the construction of hull.

Chosen Material - Dyneema fiber

Fig.2. Dyneema fiber **Structure and properties of Dyneema (UHMWPE)**

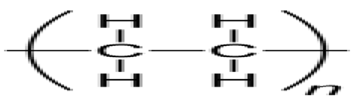


Fig. 3. Structure of UHMWPE, with n greater than 100,000

UHMWPE is a type of polyolefin. It is made up of extremely long chains of polyethylene, which all align in the same direction. It derives its strength largely from the length of each individual molecule (chain). Van der Waals bonds between the molecules are relatively weak for each atom of overlap between the molecules, but because the molecules are very long, large overlaps can exist, adding up to the ability to carry larger shear forces from molecule to molecule. Each chain is bonded to the others with so many Van der Waals bonds that the whole of the inter-molecule strength is high. In this way, large tensile loads are not limited as much by the comparative weakness of each Van der Waals bond. When formed to fibres, the polymer chains can attain a parallel orientation greater than 95% and a level of crystallinity from 39% to 75%.

In this work Epoxy is chosen as binding matrix for the composite. Epoxy resins, also known as **poly epoxides** are a class of reactive pre polymers and polymers which contain epoxide groups. Epoxy resins may be reacted (cross-linked) either with themselves through catalytic homo polymerisation, or with a wide range of co-reactants including polyfunctional amines, acids (and acid anhydrides), phenols, alcohols, and thiols. These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing. Reaction of polyepoxides with themselves or with polyfunctional hardeners forms a thermosetting polymer, often with strong mechanical properties as well as high temperature and chemical resistance. Epoxy has a wide range of applications, including metal coatings, use in electronic and electrical components, high tension electrical insulators, fiber-reinforced plastic materials, and structural adhesives. Determination of the properties of the composite **[8]** Dyneema-epoxy is given in the Table.2.

Table.2. Determination of the properties of the composite Dyneema/epoxy:

Input data:
E_f = Young's Modulus of fiber
E_m = Young's Modulus of matrix
ρ_f, ρ_m = Densities of fiber and matrix
V_f, V_m = Volume fractions of fiber and matrix
Volume fractions of fiber and matrix are
V_f = 0.7, V_m = 0.3
Densities of fiber and matrix are
$\rho_f = 970\ Kg/m^3$ $\rho_m = 1200 Kg/m^3$
Density of Composite
$\rho_c = (\rho_f \times V_f) + (\rho_m \times V_m)$
$= (970 \times 0.7) + (1200 \times 0.3) = \mathbf{1042.5\ Kg/m^3}$
Mass friction of fiber and matrix
$W_f = W_m$, $W_f = (\rho_f / \rho_c) \times V_f = 970 / 1042.5 \times 0.7 = \mathbf{0.651318}$
$W_m = \rho_m / \rho_c \times V_m = 1200 / 1042.5 \times 0.3 = \mathbf{0.34532.}$
Note:
Sum of mass Fractions
$W_f + W_m = 0.6513 + 0.3453 = 0.9966 \simeq 1.$
Volume of Composite
$\upsilon_c = \omega_c / \rho_c$ (Consider $\omega_{c = 1\,Kg}$)
$\upsilon_c = 1/1042.5 = \mathbf{9.59 \times 10^{-4}\ m^3}$
Volume of Fiber
$\upsilon_f = V_f \times \upsilon_c$
$\upsilon_f = (0.7) \times (9.59 \times 10^{-4}) = \mathbf{6.714 \times 10^{-4}\ m^3}$
Volume of Matrix
$\upsilon_m = V_m \times \upsilon_c$
$\upsilon_m = (0.3) \times (9.59 \times 10^{-4}) = \mathbf{2.877 \times 10^{-4}\ m^3}$
Mass of Fiber
$\omega_f = \rho_f \times \upsilon_f$
$= (970) \times (6.714 \times 10^{-4}) = \mathbf{0.6512\ Kg}$
Mass of Matrix
$\omega_m = \rho_m \times \upsilon_m = (1200) \times (2.877 \times 10^{-4})$
$= \mathbf{0.34524\ Kg.}$
We have,
Longitudinal Young's modulus
$E_l = (E_f \times V_f) + (E_m \times V_m)$
Here;
E_f = 110 GPa, V_f = 0.7 E_m = 3.4 GPa, V_m = 0.3
$E_l = (110 \times 0.7) + (3.4 \times 0.3)$ **=78.02 G Pa**
Transverse Young's modulus
$1/E_2 = Vf/Ef + Vm/Em = (0.7 / 110) + (0.3 / 3.4)$
$1/E_2 = 0.09459893$, $\mathbf{E_2 = 10.57\ GPa}$
Poisson's Ratio (V)
$\nu_f = 0.46$, $\nu_m = 0.3$, $V_f = 0.7$, $V_m = 0.3$, $V_{12} = (\nu_f x V_f) + (\nu_m x V_m) = (0.46 \times 0.7) + (0.3 \times 0.3)$
$\mathbf{V_{12} = 0.412}$
Major Poisson's Ratio
$V_{12} = 0.412$
Minor Poisson's Ratio
$V_{21} = (V_{12}) \text{ X } (E_2 / E_1) = (0.412) \text{ X } (10.57 / 78.02)$
$\mathbf{V_{21} = 0.055817}$
In Plane Shear Modulus
$1 / G_{12} = (V_f / G_f) + (V_m / G_m)$
We have,
$G_f = E_f / 2(1+\nu_f) G_f = 110 / 2(1+0.46) = \mathbf{37.69\ GPa}$
$G_m = E_m / 2(1+\nu_m) = 3.4 / 2(1+0.3) = \mathbf{1.308\ GPa}$
$1 / G_{12} = \frac{0.7}{37.67} + \frac{0.3}{1.308}$
$\mathbf{1 / G_{12} = 4.0332\ G\ Pa}$

IV. LITERATURE SURVEY:

A.K.Amiruddin et al **[9]** constructed proto type of hovercraft hull with aluminium (6061-T6) base which proved to be success full. In order to reduce the weight of the hover craft the thickness of the hull was decreased and the point where maximum displacement of hull occurred a rectangular supporting bars were placed. After a number of experiments, the propulsion, lifting systems were successfully demonstrated and it was concluded that the selected material would be very suitable and reliable in building up the hull of a hover craft.

In utilizing the generative structural analysis for the hull of hover craft, A.F.Aiman et al **[10]** were done a study on fiber glass composite hover craft hull base with different wall thickness. The analysis was done at different loading conditions.The with standing capacity of the hull for various thicknesses at different loads can be estimated from FEA analysis. They concluded that the displacement is more occurate than von Mises stresses. These studies suggest that use of composites is potential for carrying out studies on hull of hover crafts.

V. DESIGN OF HOVERCRAFT:

In this work the design of the hovercraft is completed using the CATIA V5R20 3D modeling software **[11].** The hull (deck) is the main structural component of a hovercraft. All four different components namely lift system, thrust system, skirt and steering will be mounted to the deck. Hence the deck must be rigid, stable, and should not flex under any loads when it hovers. No flexing will allow no anomalies in the air cushion underneath. Ribs will be added to increase the rigidity of the deck. The purpose of the ribs is to hinder the flexing tendency of the deck during operation.

5.1 Hull Design

Hull Dimensions chosen are Length: 4200 mm, Width: 2000 mm , Thickness : 40 mm shown in Fig.4 Reducing weight increases operating efficiency, so fuel efficiency and better performance involves reducing the weight of the Hovercraft.The hull design was modified by making a few changes. The thickness of the hull is being reduced. Rectangular support bars are introduced in order to decrease the weight of the vehicle without any change in its weight carrying capacity. Further, the number of supporting bars is gradually increased with decrease in the thickness of the hull. The Table.3. given below gives a clear idea about the no of supporting bars introduced for the corresponding thickness of the hull.

Table.3. No of Supporting Bars for corresponding Thickness of Hull

CASE	Thickness of hull(mm)	No. Of Supporting Bars
1	40mm	0
2	20mm	5
3	16mm	6
4	10mm	8
5	8mm	9

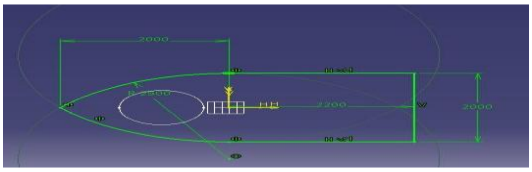


Fig.4. Dimensions of hull

5.2 Lift Fan – Background

When the craft is fully loaded, the operating weight will be approximately 270 Kgs. The fan itself must provide appropriate corresponding values of flow rate, static pressure and power to obtain the necessary hover height. Another constraint on the lift fan is its size, fan will fit into a predetermined area as the deck area is finite and many other components need to fit on the deck. The calculations were based on a 4200mm by 2000mm deck loaded with 270 Kgs and hovering at a height of 19mm. The hover height is the distance between the bottom of the skirt and the ground.

VI. CALCULATION OF LOADING FORCES:

In determining the magnitude of forces acting on the hull, the mass to be considered were the engine, payload and the hull structure, with the gravitational acceleration = 9.81 m/s2. The total forces (engine force, human force, structure force, lift force and thrust force) **[12]** acting normal to the surface of the hull (area of $8.4m^2$) are balanced pressure which is calculated by using "P=F/A", that is, pressure = force / area (Hibbeler, 1997) equation. The magnitude of the mass used to calculate the force acting on the hull is as shown in Table.4.

6.1 Lift Fan Requirements

6.1.1. Calculated Fan Performance Specifications

Lift air Volume (Flow Rate) = 3.360 m^3/s., Cushion Pressure (Static Pr) = 32.144 mm of water,Fan Power Required = 1.7654 Kw (2.3676 HP), Approximate Lift Perimeter = 12.4 m, Total hover gap area = 0.2355 m^2.

These are the bare minimum output values required and critical to design that these numbers be provided and preferably exceeded by the lift fan, if not our hovercraft will not hover.

6.1.2 Chosen Fan Dimensions

Outer Diameter=761.74 mm,

Diameter of Hub=120 mm

Diameter of shaft = 60 mm,

No of blades = 5

Table.4. Mathematical calculation of Lift force and Cushion Pressure For the two person seating capacity.

Description: Mass specification

Engine, mengine = 50 kg

Human, mhuman = 160 kg

Structures,mstructure = 60 kg

Calculation of engine force, F_{engin}

F_{engin}= Mass of engine x acceleration due to gravity = 50 x 9.81= 490.5N

Take the F_{engine}= 500N for the analysis.

F huma = human mass x gravity acceleration = (160kg) (9.81 m/s^2) = 1569.6 N

Take F_{human} = 1570N for the analysis.

F structures =structure mass x gravity acceleration = (60kg) (9.81 m/s^2 = 588.6 N

Take the $F_{structure}$ = 600N for the analysis.

Calculation of lifting force, Flifting

Fliftin = Fengine + Fhuman + Fstructure = 500 + 1570 + 600= 2670 N

Area of air cushion = length x breadth = 4.2 m x 2m = 8.4 m^2

Calculation of air pressure, Pair

Pair = $F_{lifting}$ / area = 2670 N / 8.4 m = 317.85 $N/_{m^2}$

Take the Pair = 320 N/m^2 for the analysis.

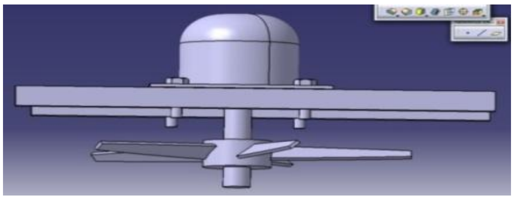


Fig.5. Lift fan 3D

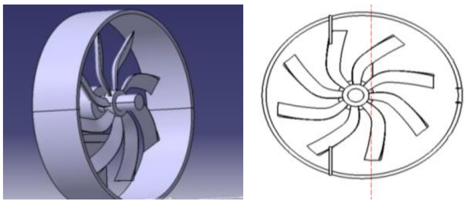


Fig.6. Thrust fan 3D, Thrust fan 2D

The above Fig.5 shows 3D image of Lift fan and Fig.6 shows 3D and 2D images of Thrust fan. The diameter of the fan is based on how much space of the deck that can be relegated to it, as well as what is commercially available to this work.

6.1.3 Fan Material

A number of materials were taken into consideration for this task. Aluminum is the material of choice as it is light enough to suit our design.

6.2. Lift Motor – Background

The most important part of the Hovercraft is the lift motor. Without it, the fan would not turn, no lift could be generated, and the hovercraft would not hover. This means that determining the necessary power output of a motor is the first calculation that must done. When the craft is fully loaded, the operating power required is 2.5 horsepower. The motor must produce this much power at a speed the fan is designed for. The main constraint on the lift motor is its weight; and need a light motor so it won't have to cut back on hovercraft payload capacity.

6.2.1 Motor Selection

The selected motor must be capable of producing calculated power i.e 2.5HP, so choose the motor power at least twice that much to make up for any losses that may occur. There are three basic types of motor to choose from; 2 stroke gasoline, 4 stroke gasoline and electric. Overall, in a perfect condition Based on a 270 kg hovercraft weight, the total thrust required is assumed to be half times the lift force required. This comes to be around 1400 N , a 2-stroke gasoline engine would be a better choice mainly because of its very favorable power to weight ratio, its inherent simplicity. However, the RPM range does not suit the application, i.e. the motor can not be directly mounted to the fan because a 2 stroke's power band is well above 6000 RPM and the fan is designed to run at 3500 RPM. This would necessitate a belt or gear system to decrease fan speed, which complicates things, and adds more weight. Because of this a 4 stroke gasoline engine rated at 5 horsepower at 3500 RPM is to be selected.

6.2.2 Motor Dimensions

Length = 10 inches, Width = 6 inches, Height = 6 inches

6.2.3 Motor Material

The engine block is made of Aluminum, like most engine blocks, because it is the lightest and dissipates heat the most rapidly, which is critical with an air cooled engine. The crankshaft is high strength steel.

6.3 Thrust - Background

The thruster's primary function on a hovercraft is to move the hovercraft forward, backward and to provide steering. In this application, the thrusters should be able to move the hovercraft at about 50 Km/hr in a reasonable amount of time.

VII. ANALYSIS:

7.1. TETRA-MESHING

Once the geometry is cleaned, the design space volume is filled with tetrahedral elements using the auto-mesh features of Hyper Mesh. This is done with a volume-tetra element with a nominal minimum size of 10 mm, and curvature and proximity adaptation enabled to refine the mesh in the regions of more complex geometry Volume tetra mesh is advanced meshing option available in Altair Hyper mesh for doing Finite element modeling. All the three views of the Hovercraft after meshing with Tetra elements are shown in Fig.7

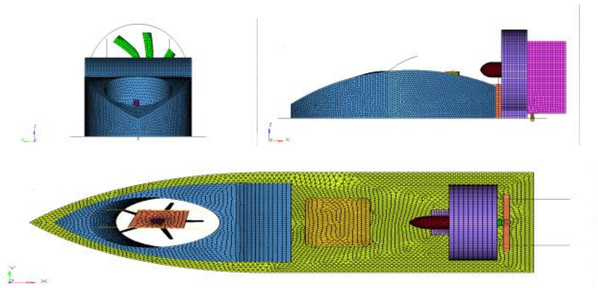


Fig.7. Front View , Side View and Top View of Hovercraft is meshed with Tetra elements

7.2.MATERIAL

After meshing is done for complete Hovercraft it is need to apply material for existing mesh. Dyneema-Epoxy material is used for Hovercraft parts like deck, seat and the material mentioned in Hyper mesh software which is shown in Fig.8 and screen shot of material collector in ALTAIR HYPERMESH software shown in Fig.9 below.

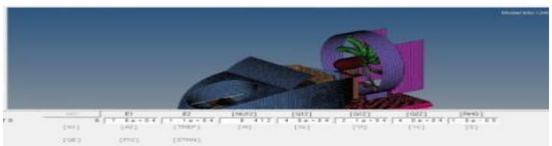


Fig.8. Screen shot of Material Properties

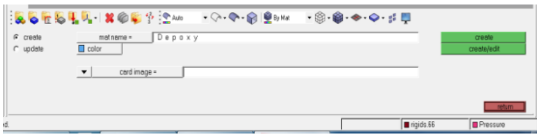


Fig.9. Screen shot of Material Collector in Hyper mesh Software

First it is need to give name for our material, then type of material like ORTHOTROPIC. Every software has its own GUI (Graphical User Interface) same way here in hyper mesh for linear static problems will use MAT8 as a default material card image. In which enter the values of young's modulus, poisons ratio and density of composite material.

7.3. ELEMENT PROPERTY

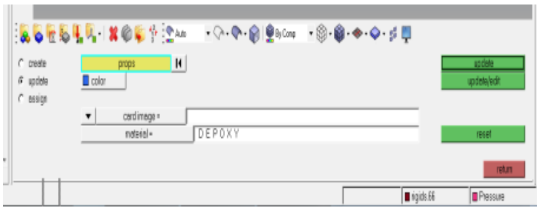


Fig.10. Property Collectors, Hyper mesh

Fig.11. Ply thickness and ply orientation

After applying material, user should take care of thickness of the shell component. For this model 2D and 3D meshing used because it is as shell metal component which will have the thickness. In hyper mesh using property collector mentioning element thickness about 2mm is selected as per suggested. Every software will have their own language in the same way in Altair Hyper mesh software for 2D elements the property will be PSHELL, for 3D elements the property will be PSOLID and for composite materials the property will be PCOMP. The Fig.10 shows screen shot of property collector, Fig.11 shows screen shot of ply thickness and orientation.

7.4. CONSTRAINT

Defining DOFs 1, 2, and 3 as translational degrees of freedom in x, y, and z; and DOFs 4, 5, and 6 as rotational degrees of freedom about the x, y, and z axes In the Fig.12. It is clearly mentioned boundary conditions for Hovercraft fixed in all three x, y and z directions. At right side of the bolt fixing location is in y and z direction. Centre hole location is fixed in x, y and z direction which doesn't move in 3 translation direction. The fixing points are assumed from the physical model and applied in virtual software and analyzed.

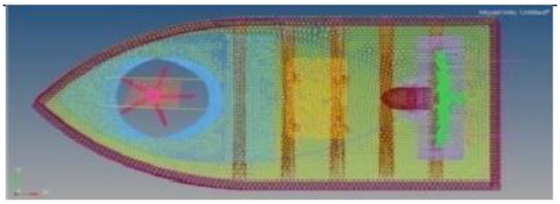


Fig.12. Defining constraint

7.5. LOADS

Force at three locations is different based on the physical effect to control arm force and moments are applied. The weights of Lift motor and thrust engine of 15kg and 35kg are acting vertically downwards as shown in the Fig.13. A pressure of 315 Pa is acting vertically upwards on the hull, shown in the form of pink arrow.

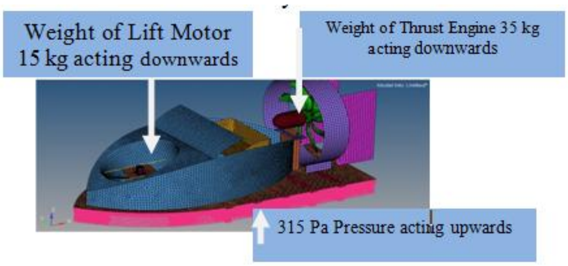


Fig.13. Forces and Pressure applied to hull

VIII. RESULTS AND DISCUSSIONS:

8.1. Variation of displacement values

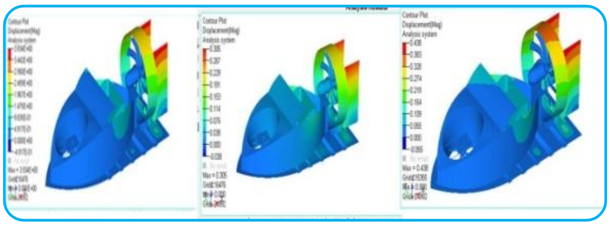


Fig.14. Variation of displacement values Baalsa Wood, Al and Dyneema-Epoxy

The comparision of displacement values for three different materials for the hover craft hull base i.e. Baalsa wood, Aluminium and Dyneema epoxy under the same loading conditions is shown in the Fig.14. Among the three different hull materials , Aluminium has given lowest displacement of 0.305mm, Baalsa wood has given highest displacement of 3.39mm.

8.2. Variation of stress values

The comparision of stress values for three different materials for the hover craft hull base i.e. Baalsa wood, Aluminium and Dyneema epoxy under the same loading conditions shown in the Fig.15, Among the three different hull materials , the induced stress of the Baalsa wood hull base is 9.4MPa, It is 1.7 times less than the allowable stress ($Baalsawood_{Yield\ stress}$=25MPa, F.O.S=1.5)16.66MPa.

The induced stress of the Aluminium hull base is 8.67MPa, It is 29 times less than the allowable stress ($Al_{Yield\ stress}$=386 MPa, F.O.S=1.5) 257MPa .

The induced stress of the Dyneema epoxy hull base is 11MPa, It is 145 times less than the allowable stress (Dyneema $epoxy_{Yield\ stress}$=2400MPa, F.O.S=1.5) 1600 MPa.

According to the these three stress values obtained, the stress value much less than allowable is very safe. Therefore the hull of hover craft made up of Dyneema epoxy material is very safe as compared to the other.

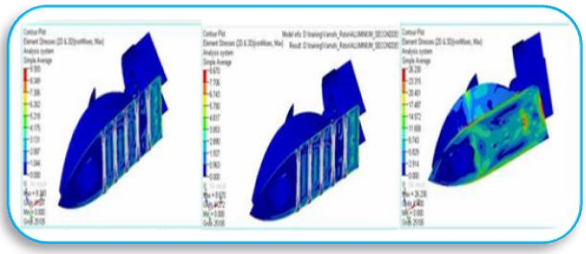


Fig.15. Variation of Stress values Baalsa Wood, Al and Dyneema-Epoxy

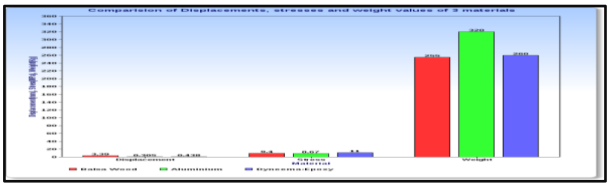


Fig.16. Comparision of displacements, stresses & weights of three material

From the table.5 It is clearly evident that there is a dramatic decrease in the weight of the Hovercraft on using Dyneema-Epoxy composite material. When compared to the weights of Hovercraft made with Aluminum, the weight is reduced by **20%** respectively. One can also observe a significant

Table.5 Comparision of displacements, stresses & weights of three material

S. No	Material	Weight	Displacement	Stress
1	Balsa-Wood	255 kg	3.39 mm	9.4 MPa
2	Aluminium	320 kg	0.305 mm	8.67 MPa
3	Dyneema-Epoxy	260 kg	0.438 mm	11 MPa

decrease in the displacement of the model wherein it decreased by **87%** compared to Baalsa wood. The bar graph shown in Fig.16. gives a clear picture about the change in values of weight, displacement and stress values of different materials. The weight of Balsa wood is very low around 255 Kg, but it can not be selected as it possess a very high displacement of 3.39 mm. Aluminium has lowest displacement of 0.305 mm, but its weight comes around 320 Kg which is very high. Hence the other material which possesses optimal weight and displacement values of 260 Kg and 0.438 respectively comes to be the best selection for the construction of hull. The selected material Dyneema-Epoxy also has 0% water absorption rate, good resistance to corrosion and very high strength to weight ratio.

8.3. Displacement Comparison for Optimized models

Table 6. Displacement Comparison for Optimized models:

Model No	Hull Thickness(mm)	No of Supporting bars	Max Displacement(mm)
1	40	0	0.419
2	20	5	0.044
3	16	6	0.153
4	10	8	0.253
5	8	9	0.462

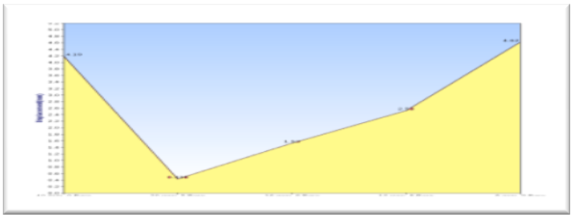


Fig.17. Variation of Max. Displacement with Hull thickness and no of Supporting bars.

The table.6. shows the comparison of Displacement for five designs of Dyneema-epoxy material. The maximum displacement occurred at the back end of the hull where the engine and thrust is located [6]. Displacements are below 1mm. Maximum displacement is seen in the Model 5 which is around 0.462 mm, where the thickness of the hull is very less around 8 mm and 9 supporting bars are introduced, Maximum displacement is seen in the Model 5 which is around 0.462 mm, where the thickness of the hull is very less around 8 mm and 9 supporting bars are introduced, whereas minimum displacement is seen in the Model 2 which is around 0.044mm and is 10 times less when compared to the maximum displacement, where the thickess of hull is 20 mm and only 5 supporting are introduced. It is aware that the design with minimum displacement is the optimal one, so Model 2 is the optimal design of all the above mentioned designed. Fig.17 shows the Variation of Max. Displacement with the Hull thickness and no of supporting bars.

8.4. Stress Comparison for Optimized Models

Table.7. Stress comparison of Hovercraft models

Model No	Hull Thickness(mm)	No of Supporting bars	Stresses Induced(MPa)
1	40	0	26.988
2	20	5	11.157
3	16	6	28.702
4	10	8	33.966
5	8	9	44.188

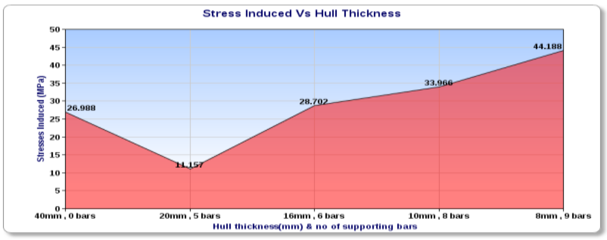


Fig.18. Stress Induced With the Variation of Hullthiknes

The above table.7. shows the comparison of Stress for five designs of Dyneema-epoxy material. Stress in all the models is below the yield point of Dyneema-epoxy material which ensures that the model will be safe. Maximum stress is found in the Model 5 and is around 44.188 MPa, where the thickness of the hull is very less around 8 mm and has 9 supporting bars. Minimum stress is seen in the Model 2 which at 11.157 MPa is around 4 times less than the maximum stress, where the thickness of hull is 20 mm and only 5 supporting are introduced.The design with least stress is the safest one, i.e. Model 2 is the safest one of all the above. Fig.18 shows Stress Induced With the Variation of Hull thickness.

8.5. Weight Comparison of Optimized Models

Table.8 Weight comparison of base model with other models

Model No	Hull Thickness(mm	No of Supporting bars	Weight of the Craft(Kg)
1	40	0	270
2	20	5	260
3	16	6	255.6
4	10	8	248.14
5	8	9	246.86

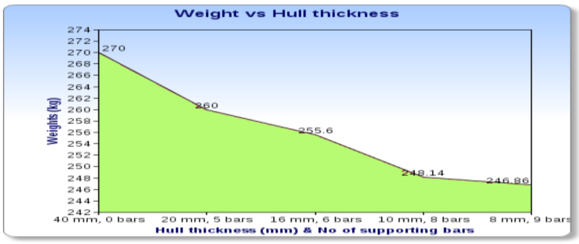
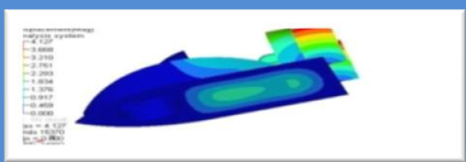
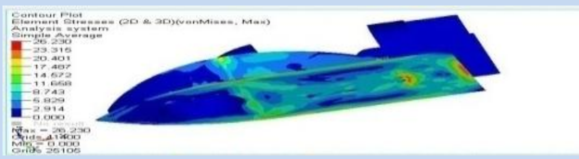
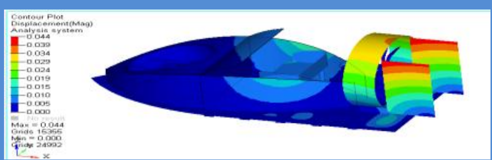
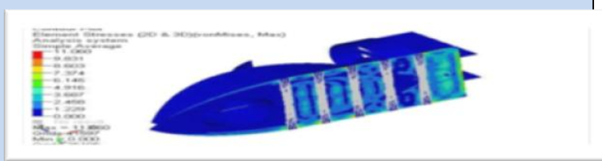
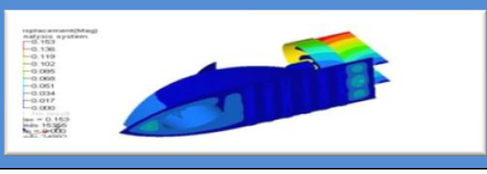
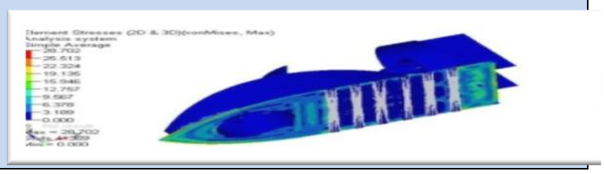


Fig.19. Variation in Weight With Variation in Hull Thickness

4% of weight is reduced from the base model and it is stiffer. As comparison of stress and displacement which is very less for the new design mode.

Table.8. above shows the Weight Comparison of Optimized Models. The component (Dyneema-Epoxy) has further undergone the structural optimization using the Hyperworks 11.0 software. The observation made from the results stated that the reduction of the weight by **4%** with a Hull thickness of 20 mm with 5 supporting bars compared to the base model having no support bars with 40 mm thickness. Variation in Weight With Variation in Hull thickness graph shown in Fig.19.

After solving the problem in Radioss the result files are obtained. Which is shown in Fig. 20. for different cases, The output files and h3d files for viewing the results in Altair Hyper view. Results are viewed in Altair Hyper view for seeing the stress and displacement of the component. By seeing above results model 2 is safer. Which is not crossed the yield point of Dyneema-epoxy material. Stress and displacement is very less for static analysis.

Case	DISPLACEMENT(mm)	STRESS (M Pa)
1	 Max. Displacement of Case (i) 4.12mm	 Max. Stress of Load Case (i) 27MPa
2	 Max. Displacement of Case (i)0.044mm	 Max. Stress of Load Case (ii) 11.157 M Pa
3		

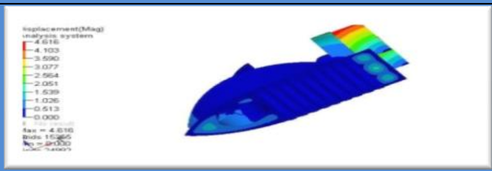
	Max. Displacement of Case (iii) 0.153 mm	Max. Stress of Load Case (iii) 29MPa
4	 Max. Displacement of Case (IV) 0.253mm	 Max. Stress of Load Case (iv) 34 M Pa
5	 The Max. Displacement of case(v)4.616mm	 The Max. Stress of Load Case (v) 44 M Pa

Figure .20. Displacement And Stress Analysed Results

IX. CONCLUSIONS:

1. Structural optimization techniques are quite effective in producing higher quality products at a lowest cost.

2. In comparision to Hull made up of Baalsa wood **87%** of the displacement reduction is obtained for Dyneema-Epoxy composite material.

3. In comparision to Hull made up of Al **20%** of the weight reduction is obtained for Dyneema-Epoxy composite material.

4. A reduction of the weight by **4%** with a Hull thickness of 20 mm with 5 supporting bars is obtained compared to the base model i.e. Hull thickness of 40 mm with 0 supporting bars of Dyneema-Epoxy composite material.

5. On whole, Dyneema-Epoxy material has **0%** water absorption characteristic, low density and high weight carrying capacity, hence it is concluded that Dyneema-Epoxy composite material is the best material for the construction of Hovercraft Hull.

X. VALIDATION OF RESULTS:

1. In the studies performed by A.F. Aiman et al using fiber glass composite hover craft hull with different wall thicknesses, it is found that the maximum displacement occurs at the back end of the Hull. In the present work also using Dyneema-Epoxy composite material with different wall thicknesses,In order to minimize the high reading (maximum) of the hull displacement ,a rectangular supporting bars was placed where the maximum displacement occurred.

2. In the work performed by above authors they obtained the maximum displacement of 0.919mm, minimum stress of 2.43 MPa at a load of 5000N for 7mm thickness of the fiber glass composite hull. In the present work also maximum displacement of 0.438mm,minimum stress of 11.157MPa at a load of 2700N for 20mm thickness of hull with 5 supporting bars is obtained. These are least displacement, stress values much less than allowable values for safe design.

3. The induced stresses of the optimized models for Dyneema-Epoxy composite material hull base are well below the allowable stress i.e. 1600MPa(for Dyneema-Epoxy composite material yield point = 2400MPa., F.O.S = 1.5),Hence the design is safe . It may be concluded that the results are validated.

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