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Transverse Structural Strength Characterization of a Deep-U Catamaran Vessel

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Abstract- This paper sets out to characterize the transverse structural behaviour of a Cork composite hullform of a deep-U Catamaran vessel (DUC) based on the conventional transverse shear force and bending moment theory and Henky's von-Mises Stress criteria. It considered the Transverse Still-water and Maximum Global wave induced loads on the vessel. Further, it ascertained the deformation and stresses imposed on the structure as a result of both the Still-water and wave-induced loads. The Still-water loads utilized existing conventional principles, whereas the wave-induced loads were derived from the vessel's hydrodynamic motion characterization based on the Modified Pierson Moskowitz Spectrum for narrow banded wave and benign sea state, solved through the numerical analysis on the ANSYS. From the analysis on the global transverse shear force (kN), the hogging and sagging shear forces exhibited similar trends, with initial increases, fluctuations, sharp reversals, and gradual recoveries. Both forces reach their maximum values at different vessel width. The Still-water transverse shear force values range from -18 kN to 18 kN. at a corresponding positions at the Still-water transverse bending moment values range from -2.2 kNm to 46 kNm. The maximum global positive transverse shear force is 121 kN, occurring at -0.45m. The maximum negative shear force is -121 kN, occurring at 0.45m. The maximum positive transverse shear force is 101 kN, occurring at -0.45m. The highest negative shear force is -101 kN, occurring at 0.45m. The shear force is zero at -1.8 and 1.8 along the vessel breadth for both hogging and sagging, indicating points where there is no maximum global transverse shear force. The maximum transverse (cross-deck/local) bending moment exhibited a hogging moment at its maximum value of 170 kNm. The values decrease symmetrically as you move away from the midpoint, reaching 0 at both port and starboard (positions -1.8m and 1.8m). The sagging moment also has its peak at the midpoint, but it is lower than the hogging moment, with a maximum of 90 kNm. Similar to the hogging moment, the sagging values decrease symmetrically towards the ends, reaching 0 at vessel breadth of -1.8m and 1.8m respectively. For the maximum transverse torsional moments, the positions along the deck where the moments are measured are: -1.8m, -1.35m, -0.9m, -0.45m, 0m, 0.45m, 0.9m, 1.35m & 1.8m represent transverse positions across the breadth of the vessel. At the midpoint (across the breadth), the hogging moment starts at 0 kNm. The values initially increase slightly (11 kNm) and then decrease to a minimum of -271 kNm at 1.35m, before slightly increasing to -261 kNm at position 1.8m. The values initially decrease slightly (-6 kNm), then increase (11 kNm) before decreasing to a minimum of -261 kNm at position 1.8m. The graph indicates that torsional moments are higher towards the ends of the deck in both hogging and sagging conditions. Wave crest acting at fore and aft perpendicular of the DUC vessel hull had loads of 103kN at the midsection of hull and near the midship a load of 51.5kN at two corners on the deck surface of the vessel were applied. This resulted in the maximum total deformation of 1.8229e-004m and maximum shear stress of 1.44MPa. The equivalent Henky's von-Mises stress criteria of 2.8677M6Pa was statically lower than the ultimate strength of 3.0MPa of the Cork composite. By this results, the structural integrity of the DUC vessel is not threatened.

Indexed Terms- Numerical, Structural, Catamaran, Strength, von-Mises

I. INTRODUCTION

Catamarans, characterized by their twin-hull structure, have garnered significant attention in marine engineering for their stability, efficiency, and versatility across various applications, including passenger transport, military use, and recreational boating. Understanding the structural response behaviour of catamaran vessels under different loading conditions is critical for optimizing design and ensuring safety. The design of a vessel structure generally involves an expert selection of the materials that are required in order to withstand numerous forces due to static loads, dynamic wave loads, hydrostatic pressures, lightship of the vessel and its components. Therefore, the forces and the resulting combinations of stresses and moments (bending and torsional) which act on the hull structure must be adequately estimated so that the structural integrity of the vessels is sufficient for its intended through-life time mission. Recent studies have focused on optimizing the structural layout of catamarans to enhance torsional stiffness without significantly increasing weight. Gao et al. (2022) employed optimization techniques based on FEA to redesign the cross-deck structure, achieving a balance between structural strength and weight reduction. Their findings suggest that optimizing internal stiffeners and employing lightweight materials such as carbon fiber composites can significantly improve the torsional stiffness of catamarans. In addition, the structure must be fit for purpose both in terms of strength, stiffness, fatigue life and cost. The ability of a vessel to maintain its smooth operations through-life depends largely on the accurate determination of its hydrodynamic behaviour especially it resistance characteristics (Chuku et al, 2017).

The core objective of this pape is to investigate the structural response behaviour of the composite cork material of the Deep-U keel hull structure to the various Still-water and wave induced loads that have been predicted and this will be performed in two distinct facets, which are;

Analyzing the Still-water and Maximum global shear force and bending moment in transverse direction of the vessel;

Assessing the strength hull structure through Henky's von-Mises stress criteria.

Therefore this paper seeks to carryout structural response characterization of the prototype Deep-U Catamaran vessel based on conventional Bending Stress Equations.

This research considered the global transverse shear force and bending moment in hogging and sagging conditions.

II. MATERIALS AND METHODS

2.1 Materials

2.1.1 Material Properties of the Hull Structure of the Deep-U Catamaran Vessel

The mission requirement for this design is specifically to combat debris in the coastal areas and as such, it is important that a lightweight vessel is utilized. Since, Catamaran vessels are essentially prone to complex geometrical configurations, it is only reasonable that a lightweight environmentally friendly material, though strong enough to withstand stress is deployed.

The composite of cork reinforced polymers will be used as the main structural materials in the design of the Deep-U keel catamaran vessel. The selected properties of the material are given in Table (1).

Table (1): Mechanical Properties of Cork Composite Material

Material Properties	Value
Material composition	Cork Composite
Relative density (t/m^3)	0.235
Young's Modulus of Elasticity (GPa)	230GPa
Poisson Ratio	0.3
Shear Modulus	8GPa
Yield Stress	0.5MPa
Ultimate Strength	1.5-3.0MPa

The composite can be fabricated or moulded as the case maybe and does not have compatibility challenges with other materials used in its alloy. The cork fibre composite material is widely applicable in the high speed craft construction duly because of the benefits it confers in terms of environmental sustainability, corrosion resistance, toughness, relative high strength and lightweight.

2.1.2 The Boundary Conditions

The structural coordinates and boundary conditions are more explicitly stated in the ANSYS simulated results attached as seen in Tables (2) and (3).

Table (2): Definition of the Structural Coordinate System

Coordinate	Direction
X,	Longitudinal direction
Y,	Vertical direction
Z,	Transverse direction

Table (3): Boundary Conditions that were applied to the Deep-U Catamaran Vessel Finite Element Model

Type of Constraints	Position of the Constraints
FIXED-X, FIXED-Y,FIXED-Z	X=0.0m;Y =1.01m & Z= -3.01m
FREE-X, FIXED-Y, FREE-Z	X=0.0m;Y =1.01m & Z= 3.01m
FREE-X, FIXED-Y, FREE-Z	X=7.9m;Y =1.01m & Z= -3.01m
FREE-X, FIXED-Y, FREE-Z	X=7.9m;Y =1.01m & Z= 3.01m

2.1.3 Summary of the Principal Particulars of the Deep-U Catamaran Vessel

After undergoing methodical dissections, the principal dimensions of the Catamaran vessels was abstracted and an accompanying model dimensions was computed as seen in Table (4).

Table (4): Summary of the Principal Particulars of the Deep-U Catamaran Vessel

Ship Principal Particulars	Full Scale
Length Overall (L_{OA})	7.9m
Length Between Perpendiculars (L_{BP})	7.5m
Overall Breadth (B)	3.6m
Demihull breadth (b)	1.2m
Demihull Block Coefficient (Demihull C_B)	0.85
Maximum speed	10knots
Waterline Length (LWL)	6.9m
Separation between centers of the demi-hulls (S_C)	2.4m
Transverse distance between the demi-hulls (S_T)	1.2m
Spacing demi-hull ratio (Sc/L)	0.133
Displacement Volume (∇)	$16.10m^3$
Mass Displacement (Δ_T)	16.51ton
Depth (D)	1.20m
Draught (T)	1.00m
Block coefficient of the Catamaran, C_B	0.85
Height of the vessels below freeboard (H_T)	1.00m
Height of the body from freeboard (H_B)	0.2m

2.14 The Structural Configuration of the Deep-U Catamaran Vessel on ANSYS

A global Finite Element (FE) model of the vessel was developed using the ANSYS program (ANSYS, 2024). The model consists of the two demi-hulls and it is rigidly connected by a cross-deck structure, otherwise also known as the Spine deck structure. The main particulars of the vessel have been defined earlier in Table (4). Since the vessel is symmetrical along the centre-line, only a half of its full scale global FE model was created. This half was then mirrored using the command tools available in the program to produce the full scale vessel. The significance of modelling a half of the vessel is that it allows for the application end-moments to the model as a cut-model – an essential requirement in the structural analysis using fixed-ends moment. On the other hand, the full scale model allows for an adequate definition of the boundary conditions and the application of the design loads at their actual position on the vessel.

The FE model was developed using sub structural units which collectively formed the half side of the vessel along the line of symmetry and mirrored to represent the full vessel. The structural configuration of the model, which consists of 3 traverse frames per meter, 34, 036 structural nodes, and 174, 351 elements were created in such a way that the stiffeners and frames were modelled as strake and homogenous elements.

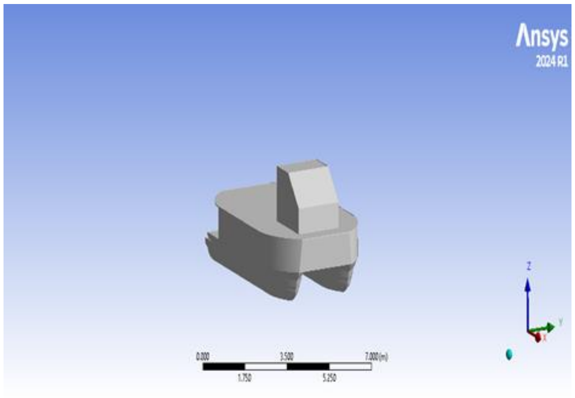

Figure 1: Front View of the Deep-U Catamaran Vessel

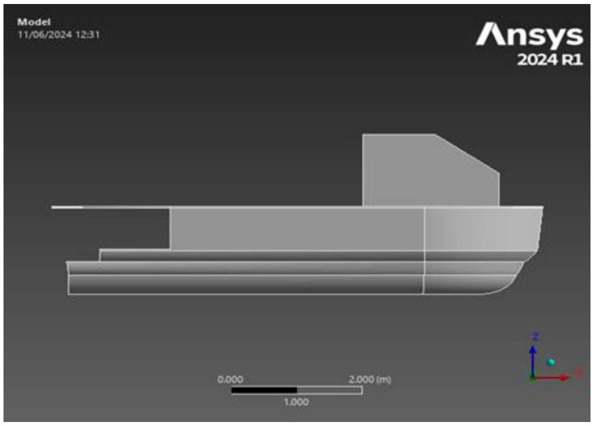

Figure 2: Profile, Body and a Global FE Model of the Deep-U keel Catamaran Vessel Developed using ANSYS

2.2 Methods

2.2.3 Stillwater and Wave-induced Shear Force and Bending Moments of the Deep-U Catamaran Vessel

Assuming the weight and buoyancy distributions are w_x and b_x, then the load distribution is given by equation (1):

q_x= b_x- w_x (1)

The distributions of the shear force and bending moment along ship length are given by equations (2) and (3):

$$F_x = \int_0^x (b_x - w_x) d_x \quad (2)$$

$$W_x = \int_0^x F_x d_x \quad (3)$$

Where:

w_x and b_x are the weight (static) and buoyancy loads respectively,

F_x is the shear force distribution along the length of the Deep-U Catamaran,

W_x is the bending moment along the ship length.

Because the distribution of load along ship length is never a continuous function, the above integrations are carried out using numerical methods and in this work, ANSYS (2024) was used to analyze the hull girder loads and moments of the Deep-U Catamaran vessel.

2.2.1 Bending Stress Determination

The ground for the initial strength design of the hull structure of a catamaran vessel is similar to that which is used for monohull in the sense that both of them largely employ the principles and assumptions of the small deflection elastic bending theory of beams and plates (Heggelund et al., 2002; Hughes and Paik, 2010). The bending theory allows for the quick determination of the stresses and strength of the hull structure using the appropriate limiting criteria and by assuming that the hull girder structure itself behaves as a simple elastic beam. The elastic bending formula is the actual basis upon which the calculations of stresses and moments that are acting on this nature of structure is predicated and it is expressed as equation (4):

$$\sigma = My/I \quad (4)$$

Where:

σ is the bending stress (MPa);

M is the moment about the neutral axis;

y is the coordinate of the plate measured from the cross section neutral axis;

I is the moment of inertia of the cross section

2.2.2 Assessment of Failure Modes and Structural Acceptability Criterion for the Computational Structural Response of the Deep-U Catamaran Vessel

The principles for the evaluation of structural adequacy for structural elements and members in the ANSYS Finite Element Program are based on failure modes of their constituent structural elements. The evaluation of these failure modes for a hull structure has been carried out based on failure of structure in yielding and buckling. These failure modes are directly dependent on the structural geometry of the ship, their appropriate boundary conditions, and most importantly, the structural loads being applied. For a given ship structural system and other relevant loading conditions, the calculated stresses must not be greater than the limits prescribed and/or computed for these failure modes (ANSYS, 2024).

The ANSYS FEA Program (ANSYS, 2024), considers a beam or plate element subjected to biaxial stress, a specific combination of stress components, rather than a single maximum normal stress component constitutes the limiting condition. In this regard, the total equivalent stress is to be based on the Hencky von-Mises criterion as seen in equation (5):

$$\sigma_e=[\sigma_x^2+\sigma_y^2-\sigma_x\sigma_y+3\tau_{xy}^2]^{(1/2)} \quad (5)$$

Where:

σ_e is the total equivalent stress

σ_x is the normal stress in the x-coordinate direction of the element

σ_y is the normal stress in the y-coordinate direction of the element

τ_{xy} is the in-plane shearing stress

For the cork composite, the total equivalent stress (σ_e) is to be less than or equal to the design stress (σ) as seen in equation (6): Thus ($\sigma_e\leq\sigma_d$).

$$\sigma_d=\llbracket 0.37\sigma\rrbracket_u \quad (6)$$

Where:

σ_u is the ultimate tensile or compressive strength of the laminate, whichever is less.

Component stresses (σx, σy, τxy) are to be less than or equal to allowable local structure design stress. (Hughes and Ma, 1996); (Hughes and Ma, 1997); (ABS, 2013) & (ANSYS, 2024).

2.2.3 Total Wave-induced Loads on Cross-Section

For a ship moving through waves, the wave loads on the vessel are generated by the incident waves, diffracted waves, and radiated waves. Additionally, the loads include the inertia force of the ship's mass and the forces resulting from changes in hydrostatic and hydrodynamic pressures due to the ship's motions. The six components of wave loads on a given cross-section, Xc, can be determined by directly integrating the inertial forces of the ship's mass forward of Xc, along with the hydrodynamic and hydrostatic pressure increments over the wetted hull surface in front of Xc, as described in equation (7). Liu et al. (1981), Brown (2012), and Heggelund et al. (2002).

$$F_j^W=\mathrm{Re}[f_J^{WLD}e^{(-i\omega_e t)}] \qquad j=2,3\ldots6 \quad (7)$$

Where:

$$f_J^{WLD}=I_j-\iint_{S_x}(p_{ht}+p_{st})\,N_j\,dS \quad (8)$$

Where:

p_{ht} is the hydrodynamic pressure

p_{st} is the hydrostatic pressure

Sx is the mean wetted surface of the transverse section

$$N_j=n_j \text{ for } j=1,2,3,4 \quad (9)$$

$$N_5=-xn_3 \quad (10)$$

$$N_6=xn_2 \quad (11)$$

$$I_2=-\omega_e^2(A_1\bar{x}_2+A_2\bar{x}_6-A_4\bar{x}_4) \quad (12)$$

$$I_3=-\omega_e^2(A_1\bar{x}_3-A_2\bar{x}_5) \quad (13)$$

$$I_4=-\omega_e^2(I_{fx}\bar{x}_2+A_4\bar{x}_2-A_5\bar{x}_6) \quad (14)$$

$$I_5=(x-s_s)I_3 \quad (15)$$

$$I_6=(x-s_s)I_2 \quad (16)$$

With

$$I_{fx}=\int_{Lx}di_x \quad (17)$$

$$A_1=\int_{Lx}dm' \quad (18)$$

$$A_2=\int_{Lx}(x-x_g)dm' \quad (19)$$

$$A_4=\int_{Lx}(z-z_g)dm' \quad (20)$$

$$A_5=\int_{Lx}(x-x_g)(z-z_g)dm' \quad (21)$$

Where m' is the sectional mass distribution along the ship length; x_s is the longitudinal coordinate of the section; i_x is the sectional mass moment of inertia about x-axis; L_s is the length between X_c; and the forward perpendicular of the ship.

III. RESULTS AND DISCUSSION

3.1 Stillwater Transverse (Cross-Deck/Local) Shear Force

The graph in Figure 3 shows the variation of transverse shear force (kN) at different vessel breadth. The data points appear to be aligned in a sequence, representing how the transverse shear force changes over the specified range of the vessel’s width. The transverse shear force values range from -18 kN to 18 kN. The values suggest a pattern that might be symmetric around the zero position, with equal positive and negative shear forces at corresponding positions. The graph likely shows the distribution of transverse shear force across a specific structure or component in

Stillwater. The forces increase to a peak (positive and negative) and then decrease back to zero. The highest positive transverse shear force is 18 kN, occurring at -0.45 kN, while the highest negative shear force is -18 kN, occurring at 0.9 kN. The shear force is zero at -1.8 kN and 1.8 kN, indicating points where there is no transverse shear force. There are several transition points where the shear force changes from positive to negative or vice versa.

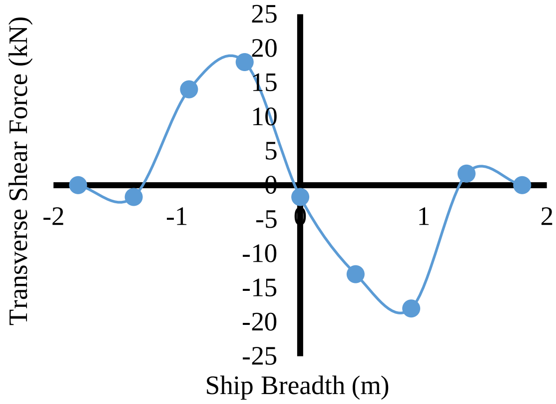

Figure 3: Stillwater Transverse Shear Force (kN)

4.3.4.2 Stillwater Transverse (Cross-Deck/Local) Bending Moment

The transverse bending moment values range from -2.2 kNm to 46 kNm. The values suggest a symmetric pattern around the 0m (centre) on the vessel breadth, with equal positive and negative bending moments at corresponding positions. The graph likely shows the distribution of transverse bending moment across a specific structure or component in Stillwater. The moments increase to a peak and then decrease back to zero. The highest positive transverse bending moment is 46 kNm, occurring at the centreline (0m) on the vessel breadth. The highest negative bending moments are -2.2 kNm, occurring at -1.35m and 1.35m on the vessel breadth. The bending moment is zero at -1.8m and 1.8m, indicating points where there is no transverse bending moment. The graph exhibits a symmetric behavior, with values on the negative side mirrored on the positive side around the center.

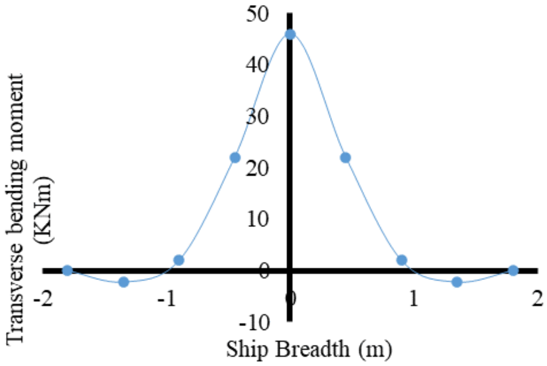

Figure 4: Stillwater Transverse Bending Moment (kNm)

4.3.4.3 Maximum Transverse (Cross-Deck/Local) Shear Force

The graph in Figure 5 shows the variation of maximum transverse (cross-deck/local) shear force (kN) under two conditions: hogging and sagging. The data points indicate how the transverse shear force changes over the specified range. The transverse shear force values range from -121 kN to 121 kN for hogging and -101 kN to 101 kN for sagging. Both hogging and sagging show symmetric patterns around the zero position, with equal positive and negative shear forces at corresponding breadth of the Deep-U Catamaran vessel. The graph likely shows the distribution of maximum transverse shear force across a point across the breadth of the vessel under hogging and sagging conditions. The highest positive transverse shear force is 121 kN, occurring at -0.45 kN. The highest negative shear force is -121 kN, occurring at 0.45 kN. The highest positive transverse shear force is 101 kN, occurring at -0.45 kN. The highest negative shear force is -101 kN, occurring at 0.45 kN. The shear force is zero at -1.8 and 1.8 along the vessel breadth for both hogging and sagging, indicating points where there is no transverse shear force. The peaks at 121 kN and 101 kN (positive and negative) represent the maximum transverse forces the structure can endure under hogging and sagging conditions, respectively. These values are critical for determining the material and design specifications to ensure the structure can handle these forces without failing. The symmetric nature of the shear forces around the zero position suggests that the structure is designed to evenly distribute the transverse loads. This balance is essential for preventing uneven stress distribution, which could lead to structural failures like cracking or buckling.

The positions at -0.45 kN and 0.45 kN are critical sections where the shear forces are highest. These sections must be reinforced or carefully designed to withstand the maximum shear forces.

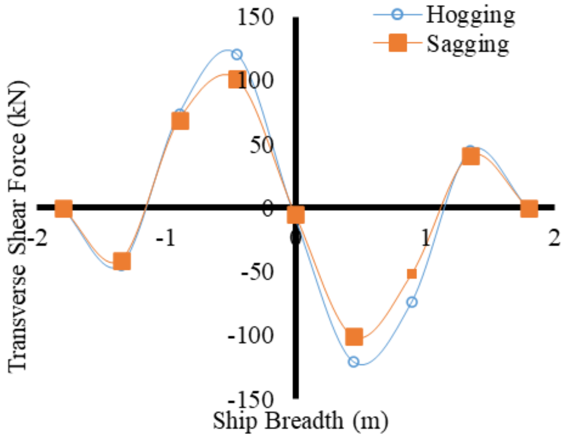

Figure 5: Maximum Transverse (Cross-deck/Local) Shear Force (kN)

4.3.4.4 Maximum Transverse (Cross-Deck/local) Bending Moment

The graph in Figure 6 illustrates the maximum transverse (cross-deck/local) bending moment in kNm. It shows two sets of data: one for hogging moments and one for sagging moments, plotted against a series of positions along the deck. At the midpoint (position 0), the hogging moment is at its maximum value of 170 kNm. The values decrease symmetrically as you move away from the midpoint, reaching 0 at both port and starboard (positions -1.8m and 1.8m). The sagging moment also has its peak at the midpoint, but it is lower than the hogging moment, with a maximum of 90 kNm. Similar to the hogging moment, the sagging values decrease symmetrically towards the ends, reaching 0 at vessel breadth of -1.8m and 1.8m respectively. The graph indicates that the bending moments are highest at the center of the deck, whether in hogging or sagging conditions, and they diminish towards the edges. The hogging moments are significantly higher than the sagging moments, suggesting that the structure experiences greater upward curvature forces than downward curvature forces.

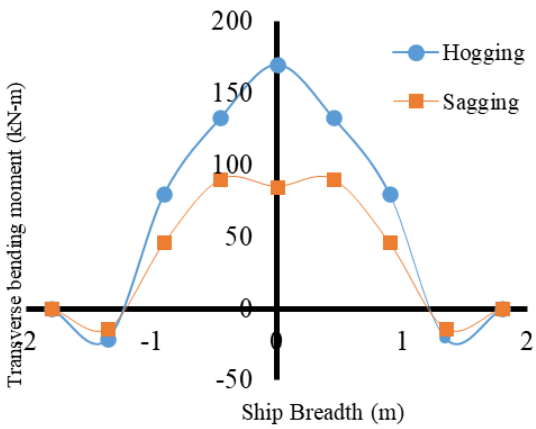

Figure 6: Maximum Transverse (cross-deck/local) Bending Moment (kNm)

4.3.4.5 Maximum Transverse (Cross-Deck) Torsional Moment

The graph in Figure 7 illustrates the transverse (cross-deck) torsional moments in kNm. Similar to the previous graph, it presents two sets of data: one for hogging moments and the other for sagging moments, plotted against the breadth of the Deep-U Catamaran vessel. The positions along the deck where the moments are measured are: -1.8m, -1.35m, -0.9m, -0.45m, 0m, 0.45m, 0.9m, 1.35m & 1.8m represent transverse positions across the breadth of the vessel. At the midpoint (across the breadth), the hogging moment starts at 0 kNm. The values initially increase slightly (11 kNm) and then decrease to a minimum of -271 kNm at 1.35m, before slightly increasing to -261 kNm at position 1.8m. The pattern shows significant torsional moments towards the outer edges of the deck. Also, at the midpoint (position 0), the sagging moment also starts at 0 kNm. The values initially decrease slightly (-6 kNm), then increase (11 kNm) before decreasing to a minimum of -261 kNm at position 1.8m. The graph indicates that torsional moments are higher towards the ends of the deck in both hogging and sagging conditions. The hogging moments generally have higher magnitudes than the sagging moments, particularly in the negative direction, which suggests a greater twisting force when the deck is under upward curvature. The central region (positions around 0) experiences lower torsional moments compared to the outer regions. Similar to the hogging moments, there are significant torsional moments towards the outer edges.

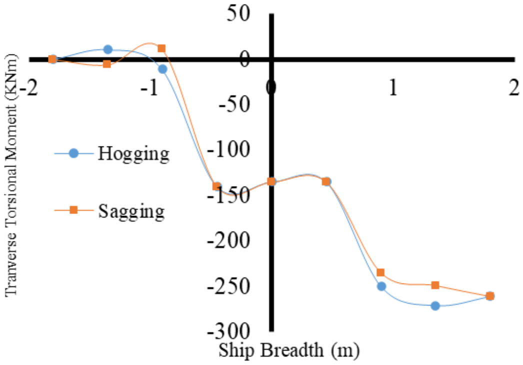

Figure 7: Transverse (cross-deck) Torsional Moment (kNm)

3.5 Numerical Stress and Deformation Examination of the Deep-U Catamaran Vessel

An arbitrary ship hull of 7.9m length (L), 3.6 m (B) and 1.2m depth (D) is taken under some non-uniform distributed loads. The L/D ratio here is 6.58 which implies that the ship can be considered as a slender beam. The material of the ship is structural cork composite. The shape of the meshes is non-uniform, the size is taken randomly, the nodal points are 34,036 and the elements were 174,351. Displacement load is applied on line 1→3 and line 4→5 of the hull model which magnitude is taken as 0. 2. The upward direction of loading is taken as positive and downward direction of loading is taken as negative for y axis.

3.5.1 Case 1: Wave Crest Acting at Midship of a Hull

The loading on the vessel for the case 1, where the reaction force here acts at the single point of wave crest located in the midsection of the hull bottom with a value of 310kN.

Wave crest located at the middle position of the ship hull has taken the whole weight of vessel, which results in the hogging effect. ANSYS has simulated the results very correctly in this regard. The values of the maximum and minimum deformation, stress and strain are shown in Table 5. The stress developed at this hogging condition is so severe that there is possibility of catastrophic break down of the vessel at the midship section. Total deformations are also shown in Figure 8 indicating the region of higher deformation and it is also an indication of the relation between developed stresses to linearly applied loads.

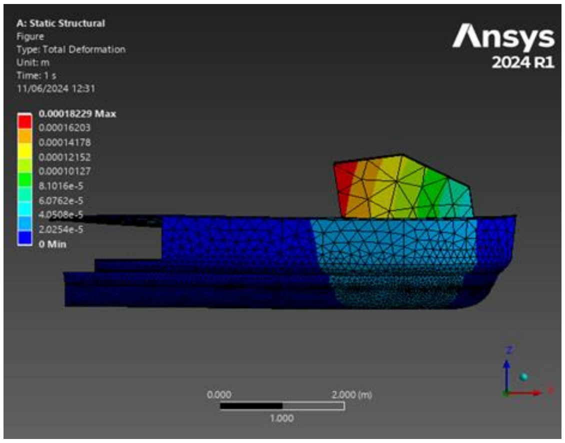

Figure 8: Total Deformation of Vessel Hull for Case 1

3.5.2 Case 2: Wave Crest Acting at Fore and Aft Perpendicular of the Deep-U Catamaran Vessel Hull

In case 2, the wave crest acting at fore and aft perpendicular of the Deep-U Catamaran vessel was first modelled, meshed and then load applied. The load applied are 103kN at the midsection of hull, 2 x 51.5kN at fore and aft side near the midship and 2 x 51.5kN at two corners on the deck surface of the vessel. As the vessel is becoming at equilibrium with the reaction forces are at two ends of the hull bottom due to the crest positions of the wave.

The value of the maximum and minimum deformation, stress and strain are shown in Table 5. The von-Misses stress criterion and the maximum shear stresses are also shown in Figures 9 and 10 respectively indicating the region of higher deformation and stress. The hull appear sagged owing to higher value of loading at the midship area on the deck of the Deep-U Catamaran vessel. Therefore, the developed stress from central loading affects the parallel body of the vessel at the highest and makes the midship region more prone to failure. Adequate strengthening is necessary to protect the hull from such failure.

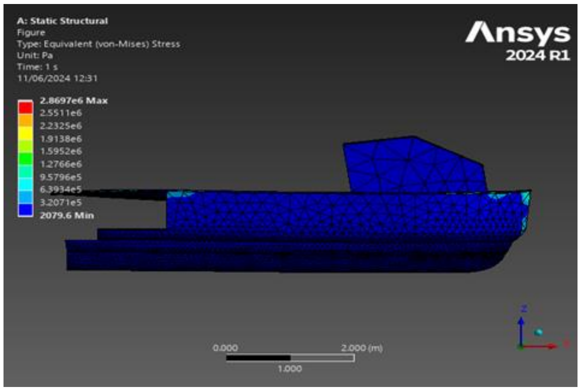

Figure 9: Equivalent von-Mises Stress (MPa)

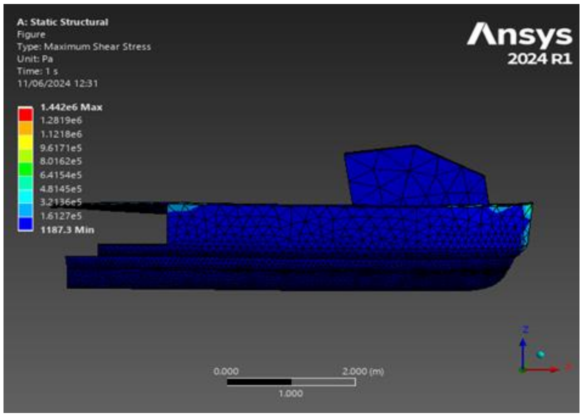

Figure 10: Maximum Shear Stress (MPa)

Table 5: Summary of the Values of the Maximum and Minimum Deformation, Stress and Strain

Type	Total Deformation (m)	Equivalent Elastic Strain(m/m)	Maximum Shear Elastic Strain(m/m)	Equivalent (von-Misses) Stress (Pa)	Maximum Shear Stress (Pa)
Minimum	0.0	1.6614e-007	1.6068e-007	2079.6	1187.3
Maximum	1.8229e-004	1.1005e-004	6.9747e-005	2.8697e+006	1.442e+006
Average	1.3347e-005	3.8331e-006	3.8514e-006	84525	44631

IV. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The hydrostatic analysis of the deep-U Catamaran vessel determined that at the design draft of 1.00m, the block, prismatic, midship area and waterplane area coefficients were discovered to be approximately, 0.85, 0.71, 0.383 and 0.421 respectively. The values of the hydrostatic characteristics at the design draft of 1.00m demonstrates the total mass displacement of the DUC to be 16.51 tonnes.

The Stillwater transverse Shear force of the Deep-U Catamaran vessel show that the simulated results appear to be aligned in a sequence, representing how the transverse shear force changes over the specified range of the vessel's width. The transverse shear force values range from -18 kN to 18 kN. The values suggest a pattern that might be symmetric around the zero position, with equal positive and negative shear forces at corresponding positions at the Still-water transverse bending moment values range from -2.2 kNm to 46 kNm.

The maximum global positive transverse shear force is 121 kN, occurring at -0.45m. The maximum negative shear force is -121 kN, occurring at 0.45m. The maximum positive transverse shear force is 101 kN, occurring at -0.45m. The highest negative shear force is -101 kN, occurring at 0.45m. The shear force is zero at -1.8 and 1.8 along the vessel breadth for both hogging and sagging, indicating points where there is no maximum global transverse shear force.

The maximum transverse (cross-deck/local) bending moment exhibited a hogging moment at its maximum value of 170 kNm. The values decrease symmetrically as you move away from the midpoint, reaching 0 at both port and starboard (positions -1.8m and 1.8m). The sagging moment also has its peak at the midpoint, but it is lower than the hogging moment, with a maximum of 90 kNm. Similar to the hogging moment, the sagging values decrease symmetrically towards the ends, reaching 0 at vessel breadth of -1.8m and 1.8m respectively. The graph indicates that the bending moments are highest at the center of the deck, whether in hogging or sagging conditions, and they diminish towards the edges. The hogging moments are significantly higher than the sagging moments, suggesting that the structure experiences greater upward curvature forces than downward curvature forces.

For the maximum transverse torsional moments, the positions along the deck where the moments are measured are: -1.8m, -1.35m, -0.9m, -0.45m, 0m, 0.45m, 0.9m, 1.35m & 1.8m represent transverse positions across the breadth of the vessel. At the midpoint (across the breadth), the hogging moment starts at 0 kNm. The values initially increase slightly (11 kNm) and then decrease to a minimum of -271 kNm at 1.35m, before slightly increasing to -261 kNm at position 1.8m. The pattern shows significant torsional moments towards the outer edges of the deck. Also, at the midpoint (position 0), the sagging moment also starts at 0 kNm. The values initially decrease slightly (-6 kNm), then increase (11 kNm) before decreasing to a minimum of -261 kNm at position 1.8m. The graph indicates that torsional moments are higher towards the ends of the deck in both hogging and sagging conditions. The hogging moments generally have higher magnitudes than the sagging moments, particularly in the negative direction, which suggests a greater twisting force when the deck is under upward curvature. The central region (positions around 0) experiences lower torsional moments compared to the outer regions.

Wave crest acting at fore and aft perpendicular of the DUC vessel hull and loads of 103kN at the midsection of hull, 2 x 51.5kN at fore and aft side near the midship and 2 x 51.5kN at two corners on the deck surface of the vessel were applied, it resulted in the maximum total deformation of 1.8229e-004m, maximum shear stress of 1.44e+006Pa and equivalent von-Misses criteria of 2.8677e+006Pa. By this results, the structural integrity of the DUC vessel is not threatened.

4.2 Recommendations

Due to unavailability of structural testing kits, it is recommended that experimental transverse structural response analysis of the Deep-U Catamaran vessel model using cork composite material is conducted.

It is also recommended that the longitudinal Still-water and Global Structural response behaviour is researched on to ascertain the strength and structural integrity of the Deep-U Catamaran when faced with buoyancy and wave loads on the longitudinal aspects.

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