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Structural Design Analysis of Helideck for an Existing Ocean-Going Vessel

Agboifoh Emmanuel[1], Ibiba Emmanuel Douglas[2], Tamunodukobipi Daniel[3]
[1,2,3]Department of Marine Engineering, Rivers State University, Port Harcourt, Nigeria
Corresponding Author: Agboifoh, Emmanuel

ABSTRACT : *This paper presents the design analysis of a helideck for an existing ocean going vesselwhich would have sufficient structural integrity to operate without failure.STAAD.Prowhich has its programming language by applying the numerical skills and finite element theory are implemented to determine the helideck shear and membrane stress, and the bending forces on the plate in x and y directions. The maximum and minimum top principal stresses of the Helideck plate, and its maximum Von Mises stresses are determined and compared. This is achieved by computing the local stiffness matrices for the individual plates, and then summing them to obtain the global matrix. From the latter, the displacements and stresses at the nodal points on the Helideck structure are computed. The results indicate that all the nodal stresses from the analysis on the helideck are less than the globally known stress limits for the steel material (with maximum limit of 440000N/mm^2. Even with requisite factors of safety, the analysis results are within acceptable limits for practical purpose. Also, for comparison and validation against STAAD.Pro, the entire helideck structure is modeled and implemented using MATLAB. Both solutions are in*

KEYWORD:*Helideck, Beam, Primary members, Plate, Pillars, Member force, Nodal displacement, Member stress*

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I. INTRODUCTION

In recent times, the increase in energy demand has led to higher exploration of oil and gas in both deep and shallow water depths. As the depth of water increases, fixed offshore structures become less suitable for application in the exploration and production of oil and gas. Need for floating structures becomes imperative. The installation, operations and decommissioning of these offshore structures require the services of supply vessels and Dive Support Vessel (DSV).

A Dive Support Vessel (DSV) is designed for diving operations carried out around oil production platforms and related installations in open water of large ocean depth. The application of DSV is not limited to diving operations; it is used for pipe laying, environmental impact assessments, mooring of Lay-barges and FPSO's and other deep offshore activities. It is also suitable for various marginal and deep field asset decommissioning.

As the distance from shore to the oilfield increases and the water depth increases, the use of shuttle vessels to convey crew to the platform becomes less attractive because of time-factor, cost implications and personnel inconveniency caused by water waves. Therefore, the need for helicopter to convey personnel and materials to DSV and other offshore platforms becomes more attractive and necessary. Hence, DSVs and other offshore platforms are designed with the provision to install helidecks for the landing and takeoff of helicopters. The landing and takeoff of the helicopter on the helideck structure may induce some significant static and dynamic loading. As a result, the helideck structure must be designed to withstand such loadings [1], [2] and [3]. Helidecks are basically composed of flat plates with primary and secondary beams, which are designed to resist static and dynamic stress deformations [2]**.** Thus, the helideck design should be adequately analyzed with a good material selection, proper structural members and their sizes.

Helideck Design Guidelines/Regulations

The use of helideck, as shown in Figure 1, is basically for accessing offshore installations such as platforms for support and transportation operations. This makes offshore fields together with their self-supporting structures useful, and operates efficiently. Availability of helideck facilitates safety during emergency evacuations and swift transportation of medics and materials. Nevertheless, helidecks operational conditions should be met during their design. The most common pancake aluminum design relies on the profiling of steel sections and modifying these to satisfy industry requirements [4]. Structural safety and design requirements (international codes) should be adhered to, in the design of aluminum helideck.

Helicopter decks, just as any other offshore floating structure, are designed to meet certain safety and structural requirements. This directs the attention of designers, builders and owners to various governmental and international regulations and guides regarding the design and operational requirements for helicopters landing on vessels or units. In general, steel or other materials with equivalent properties to withstand structural capacity, even in off-design conditions are chosen for the construction of helicopter decks. If the helicopter deck forms the deck-head of a deckhouse or superstructure, it is required for it to be insulated to class A-60 standard [5].

Figure 1: Typical Helideck Diagram Source:(Designs, 2015)

Offshore installations can be designed for a particular class of helicopters using some specific guidelines. This helps greatly in the degree of its operational flexibility, life potential predictiveness, design innovations and fabrication technology. The offshore facility's landing and take-off area should be designed for the heaviest and largest possible helicopter as may be envisaged for use. Design consideration should also be given to other loadings such as traffic, snow, fueling equipment and personnel.

For design consideration and purpose, it is presumed that single main rotor will land on the wheels of two main undercarriages or skids (i.e. if fitted). The tandem main rotor helicopter will land on the wheel or wheels of all main undercarriage centers of the specified helicopter, where it is divided equally between the two main undercarriages. However, for tandem main rotor helicopters the total loads imposed on the structure should be taken as concentrated loads on the undercarriage centers of the specified helicopter and distributed between the main undercarriages in the proportion in which they carry the maximum static loads. The concentrated undercarriage loads should always be treated as point loads; but areas where tyre-contact occurs, all assumptions should be in accordance with the manufacturer's specifications. The maximum designed departure weight, the undercarriage centers of the platform, and the maximum size and weight of helicopter, for which the deck is suitable, should be stated in the Installation/Vessel Operations Manual, and in the Certificate of Fitness. Plastic design considerations can be applied for the deck (i.e. stiffeners and plating only), while elastic considerations are compulsorily applied to the main supporting members (i.e. pillars, girders, columns trusses, etc.) [5].

Deck plating

Aluminum is used for the construction of helideck mainly in the requirements of two classification societies. This is done with the assumption that its form is the same as that of steel deck. Though this seems not feasible, it is suggested that the requirements should be re-modified to reflect the use of aluminum for the construction, and such variation should meet the requirements for strength, workability, durability and maintainability. Aluminum compared very well with that of steel.

Permanent set up is not permitted by any of the classification societies, based on principle. However, for the purpose of closed-form solutions, occasionally, the GermanishcerLloyds (GL) and Lloyds Registers of Shipping (LRS) specifications permit such designs [6]. Various sets of compensations are stipulated by DNV, GL and LRS to correct the Class Society's closed-form solutions. This is imperative because of the obvious discrepancies between the closed-form solution and test data. The former, in particular, does not correctly account for the effects of patch loads, plate parameters, the plate width to patch width ratio, etc. On this backdrop, it is difficult to state how good the inaccuracies of the class society closed-form solutions can be appropriated by a generalized fixed set of correction allowances and or factors. Hence, the recommended use of the First-Principle Procedures (FPPs).

The exploitation of the first-principle procedure could be accomplished readily via a simple factoring of the predictions by the average ratio of the test results to the predictions. Average ratios have been determined for cases since from the onset of permanent sets [6]. According to Frieze [7], the most preferred approach would be exploiting closed-forms solutions. This includes the use of empirical design curves based on Jackson and Frieze empirical model.

Generally, model predictors change alongside the results of their originating test models. This implies that necessary modifications should be made in Jackson and Frieze model for it to be consistent with results of varied test models. However, a modified Hughes' model predicts test data more accurately than the FPPs. Bearing in mind that empirical equations are model-specific. Simply implemented Hughes' formulation is evidently more reliable, in this case, than any of the Class Society closed-from solutions. It is, therefore, recommended that an equation of such be evolved to achieve a high level of accuracy. Figure 2 shows a structural overview of a Helideck.

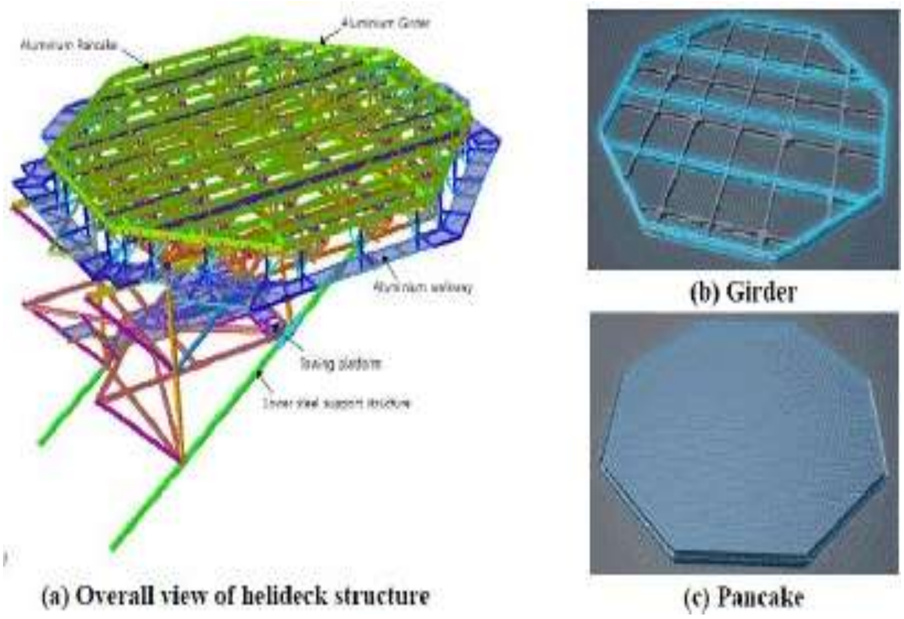

Figure 2: Helideck structural overview Sourced: (Omnisonline, 2017)

Stiffening Elements

For all the stiffening elements, a plastic-hinge method is used in this work. This is because, when there is no load factor. A plastic-hinge method can result in onset of permanent sets. Ways of resolving closed-form for stiffened plating assessment has been provided by two authorities, even though one exploits the first-yielding criterion. The two methods are derivatives of elastic principles; as such do not permit any plastic-hinge action. It is not possible to transform elastic-based formulations into plastic-hinge alternatives. It is recommended, therefore, that no attempt be made to alter the necessary requirements of these two approaches, instead the closed- form plastic-hinge approach should be used to replace the elastic-based techniques [6].

Web Strength or Beams

For steel decks of trapezoidal stiffening elements and aluminum stiffened plating: failure of web may occur due to crippling or buckling. As such, necessary checks are needed to prevent this from happening. Figures, 3 and 4, show helideck truss and frames which are parts of the stiffening members.

Figure 3: Pictorial View of a Helideck trusses Sourced:(Offshore, 2015)

Figure 4: Pictorial View of a Helideck frames Source:(abfad, 2014)

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II. MATERIALS AND METHODS

Table 1 presents the specifications of helicopter, sizes and weight to facilitate the determination of the likely service loads on the helideck; whereas Table 2 gives the list of safety factors for the various components. This is imperative to calculate the ultimate permissible load on the structural members. Table 3 displays optimal spacing between beam for different thicknesses of deck plating, and it is according to the America Bereau of Shipping (ABS) rules. The beam spacing is a function of the plate minimum thickness.

Table 1: Helicopter Size and type based on D-value and MTOM

Helicopter Name	D-Value [m]	Perimeter D Marking	Rotor Diameter [m]	Maximum Weight [kg]	Size
Bolkow Bo 105D	12.00	12	9.90	2400	Not Required
EC 135 T2+	12.20	12	10.20	2910	Not Required
Bolkow 117	13.00	13	11.00	3200	Not Required
Agusta A109	13.05	13	11.00	2600	Small
Dauphin AS365N2	13.68	14	11.93	4250	Small
Dauphin AS365N3	13.73	14	11.94	4300	Small
EC 155B1	14.30	14	12.60	4850	Medium
Sikorsky S76	14.30	14	13.40	5307	Medium
Agusta/WestlandAW 139	16.63	17	13.80	6800	Medium
Agusta/WestlandAW 189	17.60	18	14.60	8600	Medium
Airbus H175	18.06	18	14.80	7500	Medium
Super PumaAS332L	18.70	19	15.60	8599	Medium
Bell 214ST	18.95	19	15.85	7938	Medium
Super PumaAS332L2	19.50	20	16.20	9300	Medium
EC 225 (H225)	19.95	20	16.20	11000	Medium
Sikorsky S92A	20.88	21	17.17	12565	Large
Sikorsky S61N	22.20	22	18.90	9298	Large
AW101	22.80	23	18.90	14600	Large

Table 2: Values of Factor of Safety for Stress Calculation

	Plating	Beams	Girders, Stanchions, Truss Supports etc.
Overall Distributed Loading	1.67	1.67	1.67
Helicopter Landing Impact Loading	1.00	1.00	1.10
Stowed Helicopter Loading	1.00	1.10	1.25

Table 3: Beam Spacing for Different Plate Thickness

Beam Spacing [mm]	Plate thickness [mm]
460	4.0
610	5.0
760	6.0

The diagram in figure 5 shows the representation of the idealized 3D element for the representation of the framed helideck structure. Based on the assumptions that each element consists of five nodal displacements at each node the axial forces acting at the nodes of the element are f_1 and f_6; the shearing forces acting on the beam are f_2, f_3, f_7 and f_8; and the bending moment at the nodes of the element are f_4, f_5, f_9 and f_{10}. The various displacement caused by these forces and moments are represented by; axial displacement, u; displacement on the vertical axis (y-axis), v; and the displacement on the z-axis, w. Consequently, the rotation resulting from the bending moments is the first derivative of their respective displacements. Instead of numbering these displacements separately, the same convention for forces and moments is adopted, as follows:

$$u = \begin{Bmatrix} u_1 \\ u_2 \end{Bmatrix} = \begin{Bmatrix} \delta_1 \\ \delta_6 \end{Bmatrix} \quad (1)$$

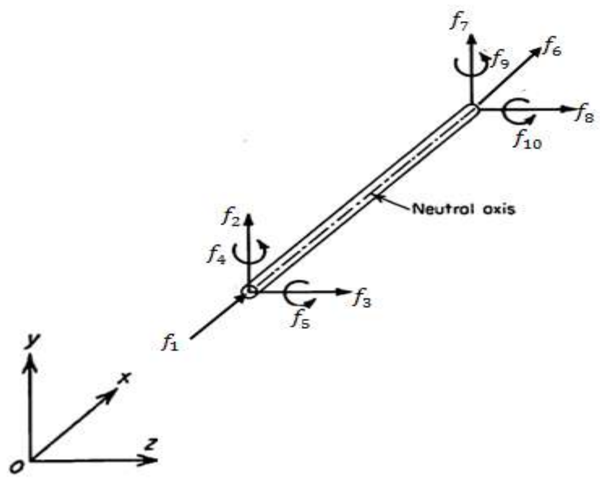

Figure 5: 3D Beam Element Idealization for the Helideck Beams

$$\mathrm{v} = \begin{Bmatrix} \mathrm{v}_1 \\ \mathrm{v}_1' \\ \mathrm{v}_2 \\ \mathrm{v}_2' \end{Bmatrix} = \begin{Bmatrix} \delta_2 \\ \delta_5 \\ \delta_7 \\ \delta_{10} \end{Bmatrix} \quad (2)$$

$$\mathrm{w} = \begin{Bmatrix} \mathrm{w}_1 \\ \mathrm{w}_1' \\ \mathrm{w}_2 \\ \mathrm{w}_2' \end{Bmatrix} = \begin{Bmatrix} \delta_3 \\ \delta_4 \\ \delta_8 \\ \delta_9 \end{Bmatrix} \quad (3)$$

The grouping of these displacement separately makes it easy for modeling the element. The axial components, y- and z-axis components of the displacements are modeled independently and added together to form the element stiffness matrix.

Determination of the Axial Displacement (u) Stiffness Matrix

Considering this mode of displacement, other modes are assumed not to be present except the axial displacements resulting from axial loading only as shown in Figure 6 The element is considered to be a linear elastic spring with cross sectional area, (A) and length, (l) supporting axial load (f) and nodal displacement (u).

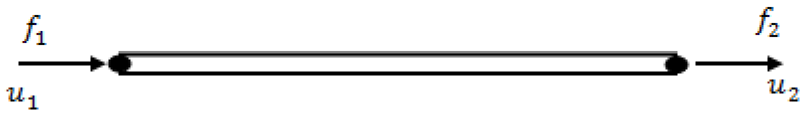

Figure 6: Bar Element for Axial Displacement

The deflection of the spring is the difference in the axial displacement:

$$\delta = \mathrm{u}_2 - \mathrm{u}_1 \quad (4)$$

From Hooke's law:

$$f = k\delta = k(u_2 - u_1) \quad (5)$$

Considering static equilibrium:

$f_1 + f_2 = 0$ or $f_1 = -f_2$

Therefore,

$f_1 = k(u_1 - u_2)$ and $f_2 = -k(u_1 - u_2)$

The above equations can be written in matrix form as

$$\begin{bmatrix} k & -k \\ -k & k \end{bmatrix} \begin{Bmatrix} u_1 \\ u_2 \end{Bmatrix} = \begin{Bmatrix} f_1 \\ f_2 \end{Bmatrix} \quad (6)$$

where: $\alpha = k = \frac{AE}{l}$;

Consequently, the stiffness matrix of the axial displacement is

$$k_a = \begin{bmatrix} \alpha & -\alpha \\ -\alpha & \alpha \end{bmatrix} \quad (7)$$

Determination of the Vertical Displacement (v) and Rotation Stiffness Matrix

The element in this case is considered to be a flexure-only-beam element. Only the vertical forces and bending moments are considered to be acting on the element resulting in vertical displacements and rotations as shown in Figure 7.

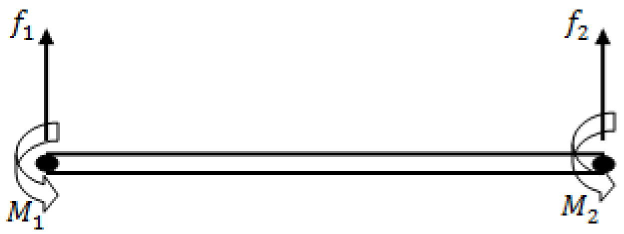

Figure 7: Flexure Only Beam Element for Vertical Displacement and Rotation

From Hughes et al [8], the flexure-only-beam element is based on the elastic theory and the element stiffness matrix is derived as

$$k = \beta \begin{bmatrix} 12 & 6L & -12 & 6L \\ 6L & 4L^2 & 6L & 2L^2 \\ -12 & 6L & 12 & 6L \\ 6L & 2L^2 & 6L & 4L^2 \end{bmatrix} \qquad (8)$$

Where: $\beta = \frac{EI}{L^3}$

I = moment of inertia

In this problem, the vertical displacement is considered due to bending and shear. As a result of the shear component, the stiffness matrix is modified. Such modification has been considered by Hughes [9] and the resultant stiffness matrix is

$$k_v = \beta_y \begin{bmatrix} 12 & 6L & -12 & 6L \\ 6L & (4+\Phi_y)L^2 & -6L & (2-\Phi_y)L^2 \\ -12 & -6L & 12 & -6L \\ 6L & (2-\Phi_y)L^2 & -6L & (4+\Phi_y)L^2 \end{bmatrix} \qquad (9)$$

where: $\beta_y = \frac{EI}{(1+\Phi_y)L^3}$

$$\Phi_y = \frac{12EI_z}{GA_{sy}L^2}$$

A_{sy} = the cross-sectional area where the shear force is assumed to act.

G = the shear modulus of the material

Determination of the Horizontal Displacement (w) and Rotation Stiffness Matrix

The horizontal displacement and rotation are similar to that of the vertical displacement. Therefore, its stiffness matrix can be derived using the same method. Considering the difference in the direction of the two elements, the stiffness matrix for the horizontal displacement and rotation is given as:

$$k_w = \beta_z \begin{bmatrix} 12 & -6L & -12 & -6L \\ -6L & (4+\Phi_z)L^2 & 6L & (2-\Phi_z)L^2 \\ -12 & 6L & 12 & 6L \\ -6L & (2-\Phi_z)L^2 & 6L & (4+\Phi_z)L^2 \end{bmatrix} \qquad (10)$$

Where: $\beta_z = \frac{EI_y}{(1+\Phi_z)L^3}$

$$\Phi_z = \frac{12EI_y}{GA_{sy}L^2}$$

Determination of the Helideck Beam Element Stiffness Matrix

The helideck beam element stiffness matrix is the summation of the above three (axial, vertical and horizontal) elements stiffness matrices. The summation of these matrices gives:

$k = k_a + k_v + k_w =$

$$\begin{bmatrix} \alpha & 0 & 0 & 0 & 0 & -\alpha & 0 & 0 & 0 & 0 \\ 0 & 12\beta_y & 0 & 0 & 6L\beta_y & 0 & -12\beta_y & 0 & 0 & 6L\beta_y \\ 0 & 0 & 12\beta_z & -6L\beta_z & 0 & 0 & 0 & -12\beta_z & -6L\beta_z & 0 \\ 0 & 0 & -6L\beta_z & (4+\Phi_z)L^2\beta_z & 0 & 0 & 0 & 6L\beta_z & (2-\Phi_z)L^2\beta_z & 0 \\ 0 & 6L\beta_y & 0 & 0 & (4+\Phi_y)L^2\beta_y & 0 & -6L\beta_y & 0 & 0 & (2-\Phi_y)L^2\beta_y \\ -\alpha & 0 & 0 & 0 & 0 & \alpha & 0 & 0 & 0 & 0 \\ 0 & -12\beta_y & 0 & 0 & -6L\beta_y & 0 & 12\beta_y & 0 & 0 & -6L\beta_y \\ 0 & 0 & -12\beta_z & 6L\beta_z & 0 & 0 & 0 & 12\beta_z & 6L\beta_z & 0 \\ 0 & 0 & -6L\beta_z & (2-\Phi_z)L^2\beta_z & 0 & 0 & 0 & 6L\beta_z & (4+\Phi_z)L^2\beta_z & 0 \\ 0 & 6L\beta_y & 0 & 0 & (2-\Phi_y)L^2\beta_y & 0 & -6L\beta_y & 0 & 0 & (4+\Phi_y)L^2\beta_y \end{bmatrix}$$

(11)

III. RESULT AND DISCUSSIONS

Table 4 presents the summary of results for the helideck design. The maximum and minimum plate center shearing stress, membrane and bending stresses are given. This tabular result enhances easy comparison of values and plate selections for optimal design.

Table 4: Maximum and Minimum Plate Center Shear, Membrane and Bending Stresses

			Shear		Membrane			Bending		
	Plate	L/C	Qx (N/mm²)	Qy (N/mm²)	Sx (N/mm²)	Sy (N/mm²)	Sxy (N/mm²)	Mx (kNm/m)	My (kNm/m)	Mxy (kNm/m)
Max Qx	523	3:COMBINATI(	**0.006**	-0.006	144.167	86.645	14.134	-0.030	-0.032	-0.004
Min Qx	515	3:COMBINATI(	**-0.007**	-0.006	83.097	99.758	-7.165	-0.043	-0.038	0.005
Max Qy	516	3:COMBINATI(	0.003	**0.011**	186.433	129.530	21.773	-0.075	-0.055	-0.008
Min Qy	517	3:COMBINATI(	0.004	**-0.022**	211.556	183.515	-4.347	-0.081	-0.066	-0.012
Max Sx	520	3:COMBINATI(	0.001	-0.021	**222.348**	174.282	-5.644	-0.065	-0.061	0.013
Min Sx	514	1:SELF WEIGH	-0.000	0.000	**0.652**	0.901	-0.037	-0.000	-0.000	0.000
Max Sy	517	3:COMBINATI(	0.004	-0.022	211.556	**183.515**	-4.347	-0.081	-0.066	-0.012
Min Sy	509	1:SELF WEIGH	-0.000	-0.000	1.850	**0.293**	-0.168	-0.000	-0.000	0.000
Max Sxy	512	3:COMBINATI(	-0.003	0.002	89.966	91.120	**79.875**	-0.042	-0.039	-0.014
Min Sxy	513	3:COMBINATI(	0.002	0.002	143.591	81.791	**-75.865**	-0.030	-0.034	0.013
Max Mx	513	1:SELF WEIGH	0.000	0.000	1.324	0.649	-0.764	**-0.000**	-0.000	0.000
Min Mx	517	3:COMBINATI(	0.004	-0.022	211.556	183.515	-4.347	**-0.081**	-0.066	-0.012
Max My	511	1:SELF WEIGH	0.000	-0.000	1.911	0.531	-0.178	-0.000	**-0.000**	-0.000
Min My	517	3:COMBINATI(	0.004	-0.022	211.556	183.515	-4.347	-0.081	**-0.066**	-0.012
Max Mxy	521	3:COMBINATI(	-0.001	0.007	131.467	80.835	-2.044	-0.046	-0.035	**0.019**
Min Mxy	518	3:COMBINATI(	0.004	0.007	124.830	81.344	9.895	-0.058	-0.039	**-0.019**

Figure 8 is the Helideck plate and trusses diagram without load. The result shows that the plate, beam, trusses and stiffeners are not stressed, and hence the blue color. The plate acts as the main surface or area upon which the helicopter lands and the beam are structural element that primarily resist loads-induced lateral deformations. The trusses provide support to the structure main frame; whereas the stiffeners are attached to the beam webs or flanges to stiffen them against out of plane deformation.

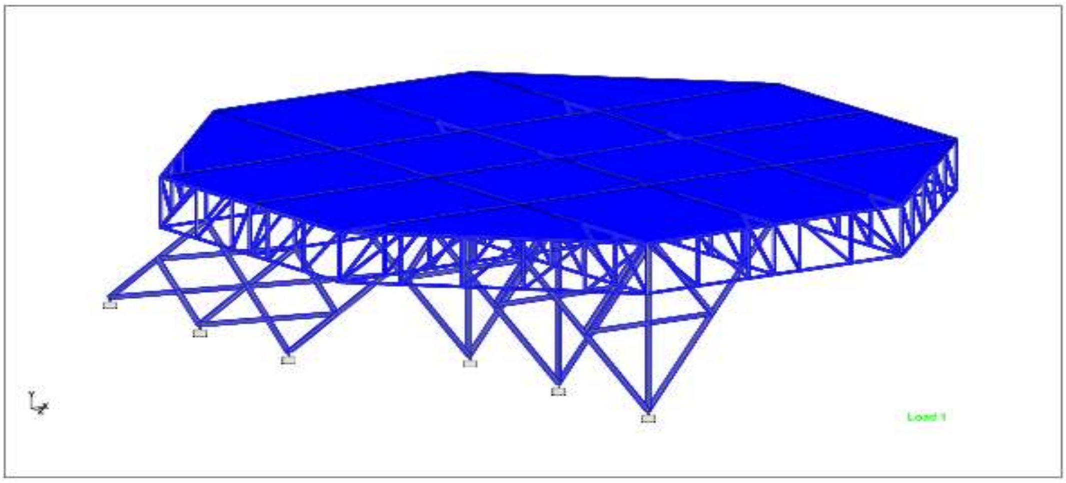

Figure 8: 3D Helideck Plate and Trusses without Load

Figure 9 is the Helideck self-weight diagram and load distribution per area. This diagram shows how the Program distributed the imparted loads on the structure based on the areas. Since the areas where helicopter landing are assumed have the highest load per unit area (stress), such areas are regarded as the danger zones. The maximum shear stress, maximum membrane stress and maximum bending force can be found in the landing regions. This result is significant because it enables designers to identify areas of excessive stress, and do a proper adjustment of structural members for stress redistribution. Such effort averts imminent failure due to local over-loading of structural members

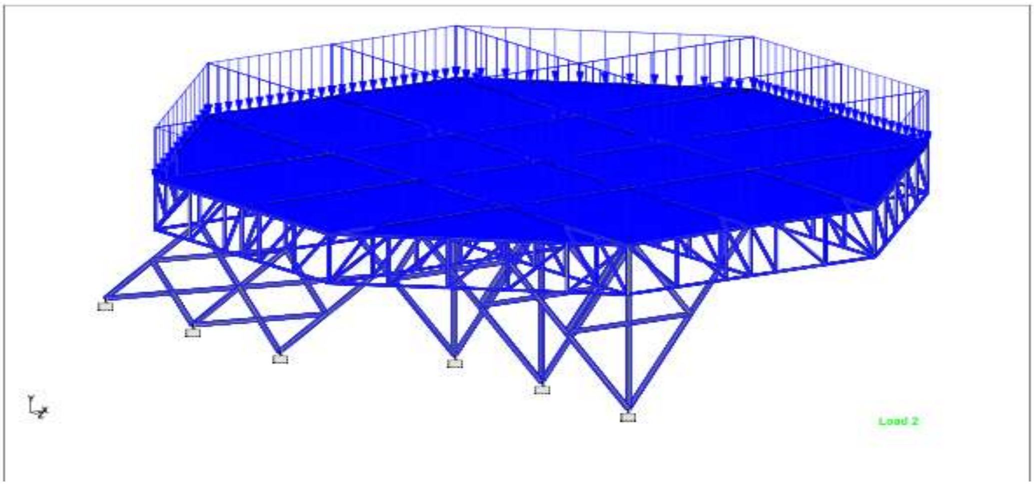

Figure 9: 3-D Diagram of the Helideck Showing the Self Weight and the Load Area

Figure 10 presents the maximum absolute stresses of the Helideck under load. This image shows the areas with maximum absolute stress. The result is important because it displays pictorially the location of the maximum stress of all the stress considered in a specific region of the plate. At the node of the plate, within the danger zone, the maximum absolute stress is less than 74.9N/mm^2 as indicated with a brown coloration; while the landing spots with the most loads have maximum absolute local stress of greater than 227N/mm^2 and indicated with red color.

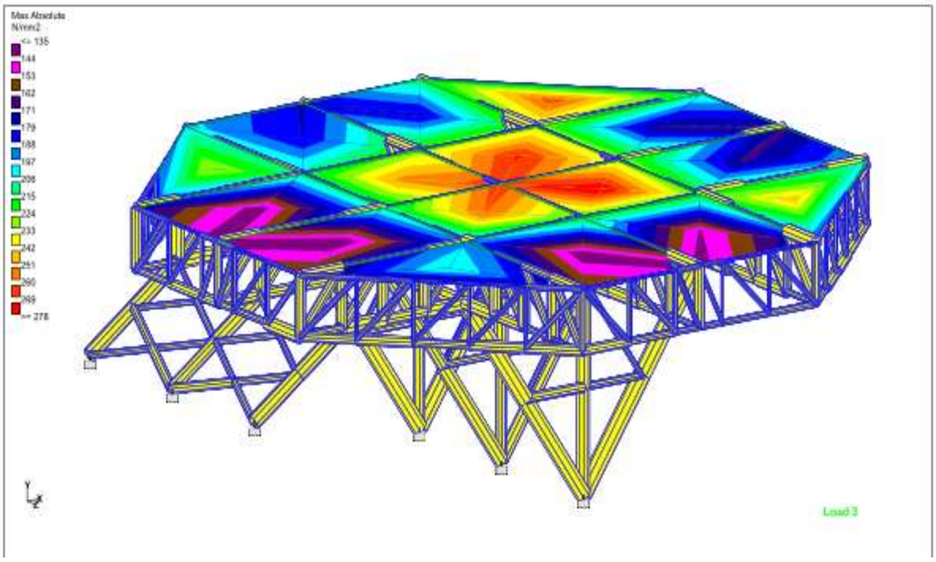

Figure 10: Maximum Absolute Stresses of the Helideck under Load

Figure 11 displays the maximum top principal stress of the Helideck under load, which is normal stress calculated at any angle where shear stress is zero. The maximum value of the normal stress is referred to as the major principal stress. The diagram indicates the node region under load with maximum top major principal stress, with different coloration on the diagram showing the various intensities of stress across the surface. Regions with less load impact at the node and with maximum top major principal stress less than 71N/mm^2 have brown coloration; while those having maximum top major principal stress greater than or equal to 219N/mm^2 are red. The red colored regions should be adequately reinforced to ensure reliability and safety.

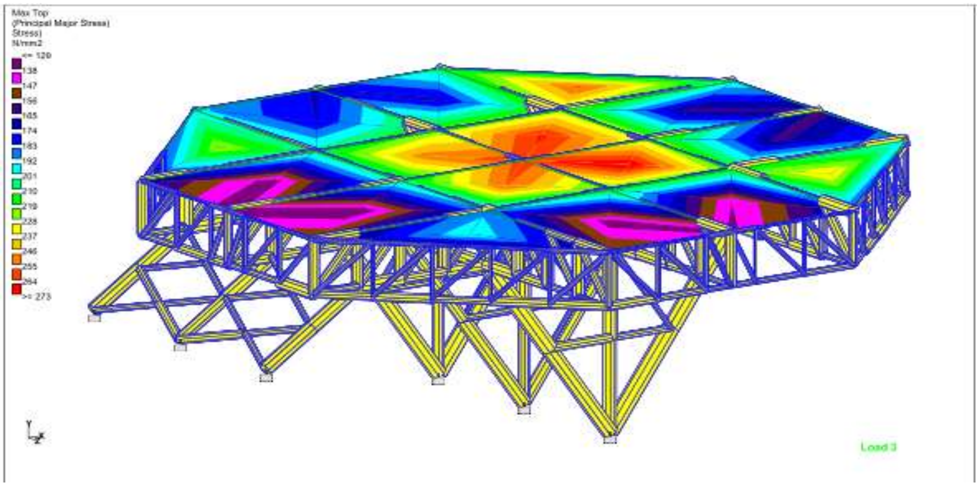

Figure 11: Helideck Maximum Top Major Principal Stresses

Figure 12 indicates the minimum top principal stress of the Helideck under load, which is a normal stress calculated at an angle where the shear stress is zero. The minimum value of the normal stress is referred to as the minor principal stress. The result shows the node regions with minimum top minor principal stress using color contrast for easy identification and classification. The nodal points are regrouped according to their stress intensity. The regions with brown coloration are less loaded, and have minimum top minor principal stresses of less than 9.09N/mm^2. Whereas the regions with the most impact load are shown on the diagram with red color and the minimum top minor principal stress is greater than or equal to 179N/mm^2.

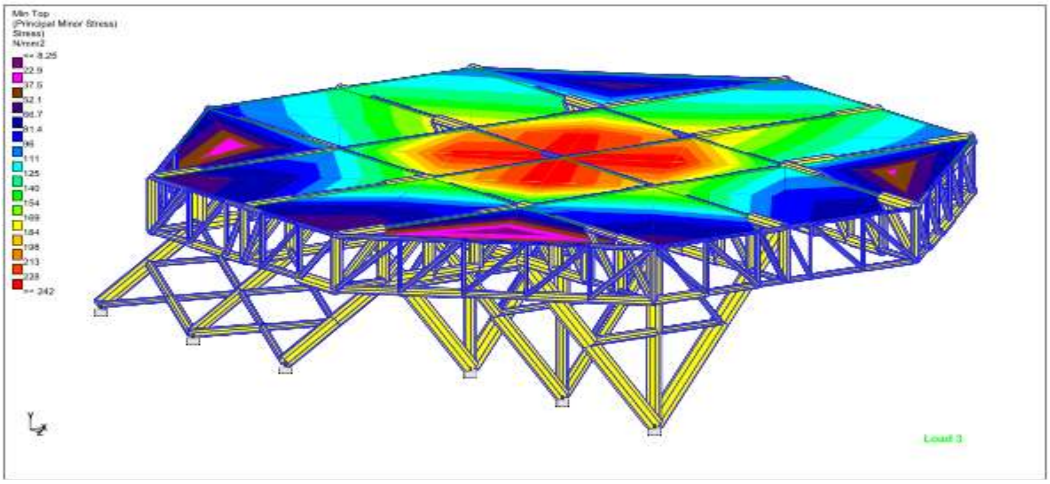

Figure 12: Helideck Minimum Top Minor Principal Stresses

Figure 13 presents the Von Mises stress of the Helideck under load. This gives the ultimate values indicating if a chosen material will yield or fracture under design-load. Thus, this analysis result reveals the possibility of material or structural failure under different service loads on the nodal sub-region of the plate. The regions with the least impact load are in brown color, with Von Mises stress of less than 67.5N/mm^2. Conversely, the regions with the most load impact or stress intensity are red, and their maximum Von Mises stresses are greater than or equal to 199N/mm^2.

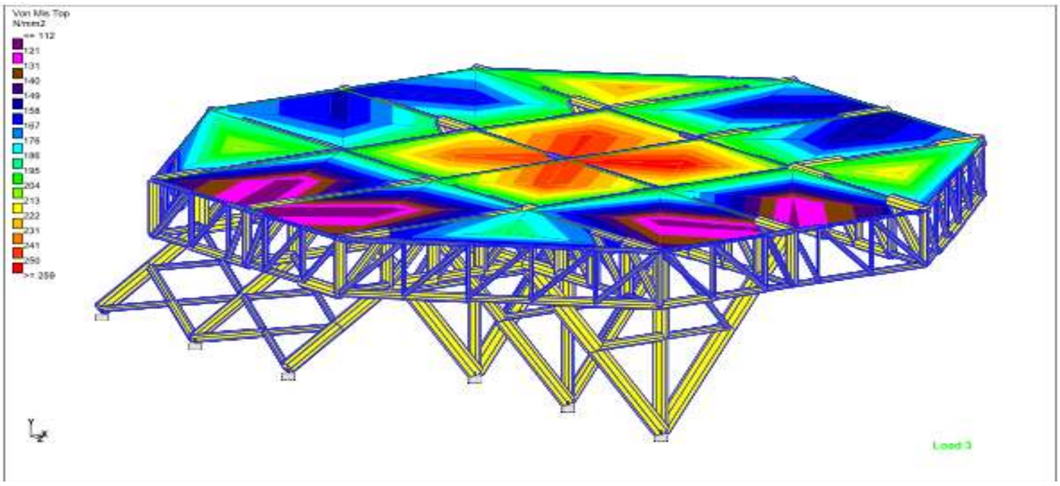

Figure 13: Helideck Von Misses Stresses

Table 5 is the plate center principal stress, Von Mises stress and Tresca stress of the Helideck. Von Mises stress represents a critical value of the distortional energy stored in the material; while Tresca stress represents a critical value of the maximum shear stress in the material, with considerations to the top and bottom plate centers. Since plate stresses are listed for the top and bottom of each active plate; the permissible service load can be determined.

Table 5: Plate Center Principal Stress, Von Mises Stress and Tresca Stress

			Principal		Von Mis		Tresca	
	Plate	L/C	Top (N/mm^2)	Bottom (N/mm^2)	Top (N/mm^2)	Bottom (N/mm^2)	Top (N/mm^2)	Bottom (N/mm^2)
Max (t)	520	3:COMBINATI(	**218.925**	227.101	199.064	206.689	218.925	227.101
Max (b)	517	3:COMBINATI(	207.614	**216.859**	194.755	203.584	207.614	216.859
Max VM (t)	520	3:COMBINATI(	218.925	227.101	**199.064**	206.689	218.925	227.101
Max VM (b)	520	3:COMBINATI(	218.925	227.101	199.064	**206.689**	218.925	227.101
Tresca (t)	520	3:COMBINATI(	218.925	227.101	199.064	206.689	**218.925**	227.101
Tresca (b)	520	3:COMBINATI(	218.925	227.101	199.064	206.689	218.925	**227.101**

The maximum top principal stress is at plate number 520 with value of 218.925N/mm^2, while the maximum bottom principal stress is at plate number 517 with value of 216.859N/mm^2. Correspondingly, the maximum top Von Mises stress is at plate number 520 with stress value of 199.064N/mm^2; while the maximum bottom Von Mises stress is at plate number 520 with stress value of 206.689N/mm^2. Similarly, the maximum top Tresca stress of the center plate is at the plate number 520 with top stress value of 218.925 N/mm^2, while maximum bottom Tresca stress is also at plate number 520 with bottom stress value of 227.101 N/mm^2.

Table 6 presents the steel beam design parameters for the track and other primary members of the Helideck and their stresses. Also, structural deformations and failures are considered against the ultimate stress limits. Such analyses are necessary for optimal and reliable helideck.The structural members are arranged in such a way that the expected load induces a fairly uniformly distributed stress; despite the fact that the imposed loads on the structure are more like point loads.

Table 6: Plate Center Shear Stress, Membrane Stress and Bending Stress

			Shear		Membrane			Bending		
Plate	L/C	Node	Qx (N/mm²)	Qy (N/mm²)	Sx (N/mm²)	Sy (N/mm²)	Sxy (N/mm²)	Mx (kNm/m)	My (kNm/m)	Mxy (kNm/m)
508	1:SELF WEIGH	2	-0.000	-0.000	0.944	1.988	-0.129	0.000	0.002	0.001
		177	-0.000	-0.000	1.248	1.785	0.125	0.000	0.001	-0.001
		171	0.000	-0.000	2.063	1.426	-0.305	-0.001	-0.002	-0.001
		83	0.000	-0.000	1.759	1.628	-0.559	-0.002	-0.003	0.001
508	2:LIVE (HELIC	2	0.000	-0.004	31.066	77.485	-5.645	0.001	0.055	0.034
		177	0.000	-0.003	42.446	69.536	4.738	0.008	0.042	-0.036
		171	0.001	-0.003	77.901	54.852	-11.356	-0.019	-0.075	-0.029
		83	0.001	-0.004	66.521	62.801	-21.739	-0.084	-0.102	0.041
508	3:COMBINATIC	2	0.001	-0.009	78.985	196.494	-14.293	0.002	0.140	0.086
		177	0.001	-0.008	107.861	176.338	12.020	0.019	0.106	-0.091
		171	0.004	-0.008	197.641	139.126	-28.818	-0.048	-0.191	-0.073
		83	0.004	-0.009	168.764	159.282	-55.131	-0.214	-0.260	0.104
509	1:SELF WEIGH	27	-0.000	-0.000	1.796	0.026	-0.168	-0.000	0.002	0.000
		2	-0.000	-0.000	1.796	0.559	-0.168	-0.001	0.002	0.000
		83	-0.000	-0.000	1.958	0.293	-0.168	-0.000	-0.004	0.000
509	2:LIVE (HELIC	27	-0.000	-0.003	77.310	6.767	-4.563	-0.017	0.043	0.000
		2	-0.000	-0.003	77.310	28.311	-4.563	-0.023	0.043	0.000
		83	-0.000	-0.003	82.156	17.539	-4.563	-0.020	-0.119	0.000
509	3:COMBINATIC	27	-0.000	-0.008	195.791	16.954	-11.642	-0.043	0.109	0.000
		2	-0.000	-0.008	195.791	71.559	-11.642	-0.059	0.109	0.000
		83	-0.000	-0.008	208.130	44.256	-11.642	-0.051	-0.302	0.000
510	1:SELF WEIGH	177	0.000	-0.000	1.122	1.930	-0.309	-0.000	0.001	0.001
		4	0.000	-0.000	0.834	1.874	0.107	0.001	0.002	-0.001
		85	-0.000	-0.000	1.906	1.285	0.515	-0.001	-0.003	-0.001
		171	-0.000	-0.000	2.195	1.341	0.099	-0.001	-0.002	0.001
510	2:LIVE (HELIC	177	0.000	-0.003	37.494	74.870	-10.947	-0.006	0.036	0.025
		4	0.000	-0.003	27.058	73.124	5.395	0.014	0.053	-0.038
		85	0.000	-0.003	72.515	50.013	20.153	-0.040	-0.082	-0.033
		171	0.000	-0.003	82.951	51.760	3.812	-0.046	-0.082	0.030

The helicopter which is the main load on the Helideck is not a distributed load but a point load because it lands with its legs. This is the main reason why all the stresses in the helideck have their maximum at the center, as indicated by red coloration. These high stress regions correspond to the expected points of landing. Since the stress is more at the center, a repeated cycle of landing and take-off at such locations may eventually result in structural failure of the helideck. Therefore, a properly designed, stiffened and framed helideck is achievable via a veritable design procedure.

Apart from the helicopter load, others that have significant effects on the Helideck are dynamic loads due to winds and waves on the vessel. These loads are considered and compensated for in this design by implementing appropriate load factor of approximately 1.5 of the helicopter loads. For this design analysis, the expected maximum weight of the helicopter is 6,800 tons, while the design weight is 11,000 tons: giving a margin of 4,2000 tons or a safety factor of 1.62.

IV. CONCLUSION

Structural Design Analysis of Helideck for an Ocean Vessel is performed using virtual tools. The stress, displacement and susceptibility to failure are investigated by numerical models. To determine the helideck structural integrity, the principal stresses of structural members are compared to Von Mises (ultimate principal) stresses and Tresca (maximum shear) stresses. Stress analyses with STAAD Pro and by Hughes' empirical model based on MATLAB source code are made and results compared.

From the results, the maximum stresses occur at the landing spots of the Helideck, because the helicopter load is rather a concentrated load than a distributed one. The maximum principal stress of the Helideck under load is normal stress and occurs at any angle where shear stress is zero. The same is true for the minimum principal stress of the Helideck. Despite the helicopter load, wind and waves also impose dynamic loads on the helideck. This is readily compensated for by utilizing appropriate load factors. The nodal stresses (227,101 N/mm^2) obtained in the analysis are less than that of the globally known stress limit for a steel material with the maximum stress limit of 444000N/mm^2: that is 51%. The results show that the design is within permissible limits for steel materials, because the maximum stress on the primary members (beams) is less than the maximum limit for steel material 444000N/mm^2. It can be concluded that the stresses and displacements data generated by the developed MATLAB model are in good agreement with those of STAAD.Pro.

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