DESIGN TECHNIQUES OF THE HELICOPTER DECK AND THE SUPPORT STRUCTURE OF THE OFFSHORE SHIPS

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Abstract: *The design of the helicopter deck structure requires the following resistance calculations: yielding, buckling, fatigue, tubular capacity, vortex shedding of the supporting structure (pipes), lamellar tearing and lifting calculation. In this work, only the yielding calculations have been presented, following that the other calculations will be presented in other works. A special attention was given to the estimation of the initial conditions that have been the basis of the design of the structure, the results obtained as well as their implementation.*

Keywords: *naval, finite element, stress, helideck*

1. Introduction

Floating production units without pipeline infrastructure have been used in offshore areas for a long time. Offshore structures have developed along with the search for new oil reserves at ever greater depths. Since the offshore structures remain anchored for a long period of time in a site, the helicopter has a very big role for supplying and transporting people on board. In this article, the emphasis was placed on the design of the helideck deck structure taking into account the rules of the aviation registers and the rules of the classification society regarding its location and the calculation of resistance in landing or navigation conditions. The structural design of offshore structures and the other related DNV-GL rules and standards are applied to verify the strength of the helicopter deck structure and its supporting structure.

2. Model description

The location of the helicopter platform center is at Fr.66 on longitudinal direction and at 21250 from center line, port side on transversal direction. The 3D finite element model can be seen in Fig. 1 and it has been developed according to the existing hull drawings.

The finite elements model presented in this chapter has been used to develop the direct stress analysis necessary to verify the helideck structure (only steel part) and the hull.

The mesh size is generally ¼ of the regular spacing according to Ref. [1].

The following types of elements are used to model the helideck structure and the hull supporting structures:

- Plate elements for: hull supporting structure: shell, decks, longitudinal and transversal bulkheads, webs, stringers, platforms, brackets and the web of HP stiffeners;
- Bar elements for: ordinary stiffeners and primary and secondary supporting structure members face plates, platform pillars;
- Rod elements for: bulb of HP stiffeners for hull supporting structure and for helideck structure;
- Rigid elements for: the link between master node placed in the way of the neutral axis

of the fore end section (used to apply enforced displacements) and its slave nodes; links between masses of different non-structural equipment's or access platforms to helideck platform;
- Mass elements for: masses of the access platforms structures and of the helicopter.

The model is sufficiently large to ensure that, the FE analysis results are not significantly affected by the assumptions made for boundary conditions and loads.

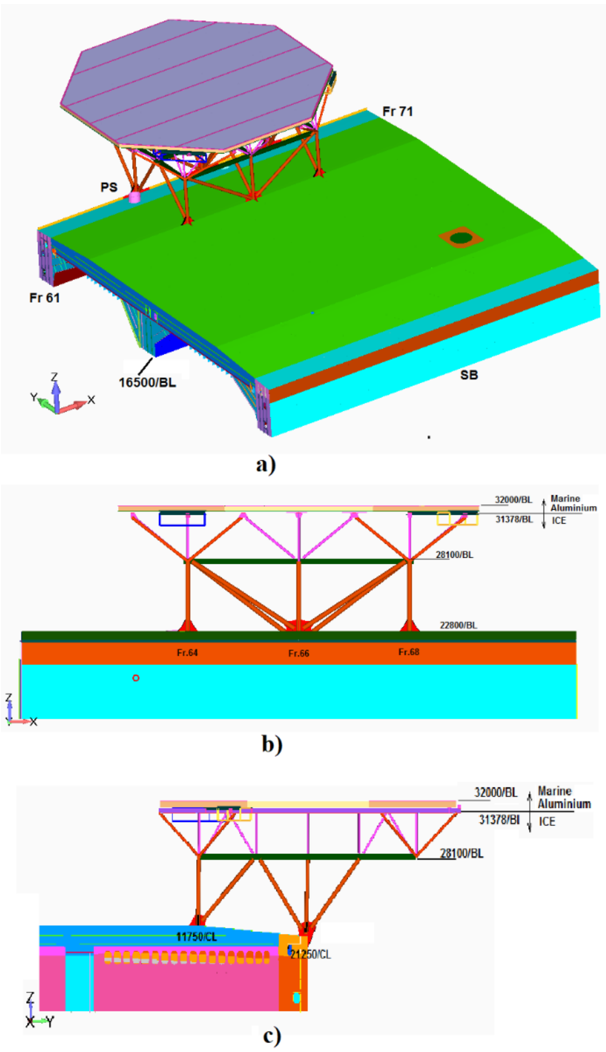

Figure 1: *Finite elements model of the hull structure and helicopter platform a)-Isometric View, b)-Longitudinal View c)-Transverse View*

2.1. Assumptions and Limitations

For the present study, the following assumptions and limitations have been considered:
- The analyses are performed by means of FE models and by hand calculations based on formulas given by rules and standards;
- The analyses are based on a linear static calculation;
- The hull girder loads and boundary conditions are determined based on the simple theory of bending;
- The environmental conditions have been considered;
- An uniform wastage of 1 mm from the as-built thicknesses of the existing structures has been adopted in order to take into consideration the corrosion during past operating life;
- For a consistent green sea load calculation approach, Ref. [7] has been used to establish the maximum height at which the green water loads may be applied and the green sea load calculation has been performed using the formula presented in Ref. [1], Sec.11.
- Taking into account that the helideck pancake will be delivered by a supplier, the helideck pancake will have an estimated weight of 43 tons. To take into account the helideck pancake weight including all equipment (lights, cables, and piping) in the finite elements model, a platform with the corresponding weight has been modeled with plate elements.

2.2. Boundary Conditions

The boundary conditions have been adopted so that to take into consideration the influence of the hull girder loads on the local finite elements model.

According to the theoretical approach:
- The aft end section of the considered hull slice (Fr.62) is considered clamped;
- Enforced displacements and rotation are applied on the nodes of fore end section (Fr.72) of the hull slice in order to model the influence of the hull girder loads. A rigid element is used in the fore end section of the model in order to apply the enforced displacements and rotation to all nodes of the section simultaneously. The rigid

element master node is placed in centerline, at neutral axis level.

- Enforced displacements are applied on the nodes of the lower end of the hull slice.

In order to determine and model the enforced displacements and rotation, the following data are needed: inertia moment of the characteristic cross-section (Fr.66), neutral axis position above base line, total bending moment.

The boundary effects have been checked to avoid unrealistic stresses induced in the areas of interest.

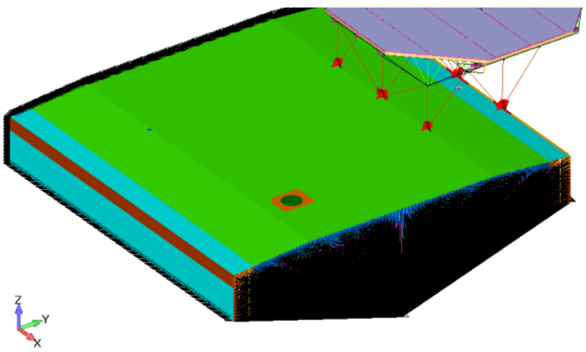

Figure 2: *Boundary conditions*

2.3. Loads and load combinations

2.3.1. Hull Girder Loads

The hull girder loads have been taken into consideration based on the methodology presented in Ref. [4] and are imposed as enforced rotation, longitudinal direction translation and vertical direction translation for the nodes of the fore end and lower section of hull structure.

Table 1: *Total bending moments*

Conditions		Bending moments [kNm]
Landing	LC-S	-8800000
	LC-H	8600000
Transit	LC-S	-9700000
	LC-H	9540000

2.3.2. Inertia Loads

The inertia loads acting on the corresponding helideck structure and hull supporting structure, on X, Y and Z direction, are taken into account by using the longitudinal (a_x), transversal (a_y) and vertical accelerations (a_z). The accelerations have been adopted according to for landing and transit conditions and have been modeled as body accelerations.

Table 2: *Accelerations*

Conditions		a_x [m/s^2]	a_y [m/s^2]	a_z [m/s^2]
Landing	LC-S	1.24	3.41	2.62
	LC-H	1.50	3.59	2.91
Transit	LC-S	1.71	4.21	3.45
	LC-H	1.84	4.35	3.73

2.3.3. Wind Loads

The wind loads are considered according to Ref. [6], Ch. 2, Sec.2, A201 and modelled as normal pressure for plate elements and distributed load for bar elements. The wind loads have been calculated using gust wind.

$V_{1min10m}$ = 30m/s for the landing condition and $V_{1min10m}$ = 55m/s for the transit condition have been used as a basis for calculating the gust wind velocities.

The mean wind speed over an averaging period T at a height z_{ASL}, $U_{T,z}$[m/s], is determined according to Ref. [7], Ch.2.3.2.11.

$$U(t,z) = U(t_r,z_r)\left(1.0 + 0.137 \cdot ln\left(\frac{z}{z_r}\right) - 0.047 \cdot ln\left(\frac{t}{t_r}\right)\right)$$

where t_r = 10 min and z_r = 10m.

$$U(t_r,z_r) = \frac{U(t,z)}{\left(1.0 + 0.137 \cdot ln\left(\frac{z}{z_r}\right) - 0.047 \cdot ln\left(\frac{t}{t_r}\right)\right)}$$

For **landing conditions** the wind velocity is:

$$U(10min, 10m) = 27.07 \left[\frac{m}{s}\right]$$

For z = 32 m – 14.57m (T) = 17.43 m above sea level the wind velocity is:

$$U(3s, 17.43m) = 35.9 \left[\frac{m}{s}\right]$$

The wind pressure is: $p = \frac{1}{2}\rho U(3s, 17.43m)^2$

$$p_{landing} = \frac{1}{2} \cdot 1.226 \cdot 35.9^2 = 787 \left[\frac{N}{m^2}\right]$$

For transit conditions the wind velocity is:

$$U(10min, 10m) = 49.6 \left[\frac{m}{s}\right]$$

$$U(3s, 17.43m) = 65.7 \left[\frac{m}{s}\right]$$

The wind pressure is: $p = \frac{1}{2}\rho U(3s, 32m)^2$

$$p_{stowed} = \frac{1}{2} \cdot 1.226 \cdot 65.7^2 = 2642 \left[\frac{N}{m^2}\right]$$

2.3.4. External Sea Pressure

According to Ref. [1], Sec.5, A105 the external sea pressure is to be considered on the hull structure.

For LC-S, no external pressure has been considered (the sea level is below the lower limit of the FE model). For LC-H, the external sea pressure on side has been determined, based on the values given for the long term sea pressure.

The maximum sea pressure for Fr.66 is 161kN/m^2 at z = 13.3m above base line; the sea pressure decreases linearly above 13.3m. The following law is applied to determine the sea pressure on sea side of the finite elements model:

$$p_{zmax} = p_{zmin} - \rho_{water} \cdot g \cdot (z_{max} - z_{min})$$

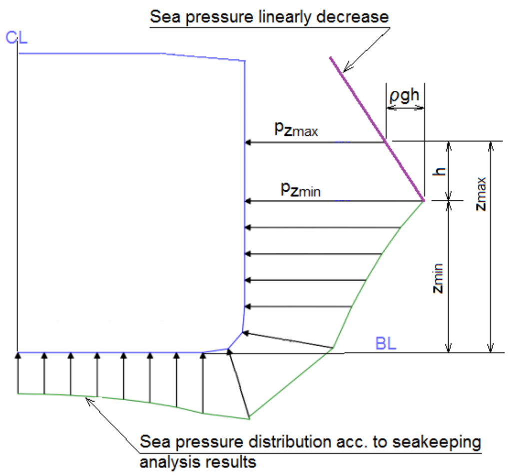

Figure 3: *Sea pressure distribution on side shell*

The lower limit of the FE model is 16.5 m therefore the sea pressure on the model sides has been determined using the above law (for the linearly decreasing sea pressure).

The minimum and maximum values of the external sea pressure obtained for the minimum and maximum height of the FE model at side are presented in Table 2.

Table 2: *External sea pressure on side*

	Sea pressure [kN/m^2]	
	z = 16.5 m above base line	z = 22.0 m above base line
LC-H	128	73

2.3.5. Landing Forces

According to Ref. [2], Sec. 2, B200, the total vertical force from the helicopter during landing has been taken:

$P_v = 2 \cdot g \cdot MTOW = 235832[N]$,

where MTOW = 12020[kg] represents maximum helicopter take-off.

The total force P_v shall be considered as distributed on the helicopters' landing gear in the same manner as when the helicopter is resting on a horizontal surface and the helicopters' center of gravity is in its normal position in relation to the landing gear.

The distance between the main wheels is 3.18m and between front wheel and the main wheels is 6.2 m.

Figure 4 shows the 6 worst positions for structure considered for landing.

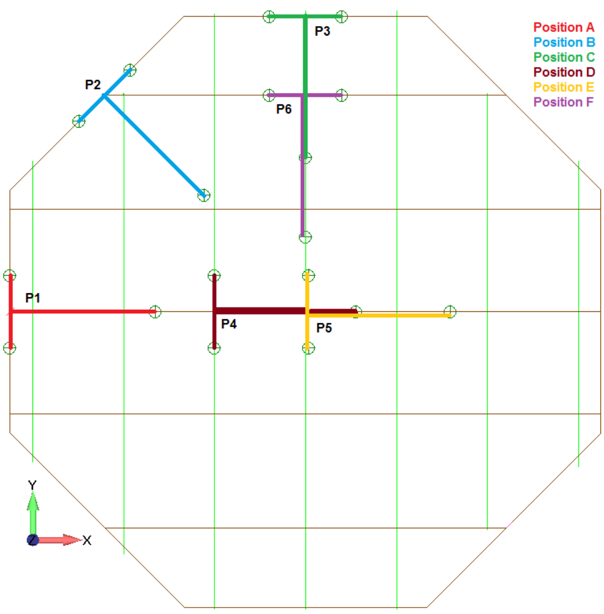

Figure 4: *Helicopter Landing Positions*

2.3.6. Load Combinations

The direct calculation of the helideck structure and the supporting structure has been based on the most unfavorable of the following conditions: landing condition and transit condition, helicopter lashed on-board a sea,

For landing condition the following loads have been considered:

-hull girder (wave 1 year return period);

-landing forces;

-gravity and inertia of the structure with equipment (wave 1 year return period);

-wind loads ($v_{1min.10m}$ = 30 m/s);

-snow;

-ice;

-external sea pressure;

-tank pressure.

For transit condition the following loads have been considered:

-hull Girder (wave 100 year return period);

-gravity and inertia of the helicopter (wave 100 year return period);

-gravity and inertia of the structure with equipment (wave 100 year return period);

-wind loads ($v_{1min.10m}$ = 55 m/s);

-snow and ice;

-external sea pressure;

-tank pressure.

-green sea on pillars erected helicopter decks.

4. Results

The yielding check results are presented separately for the helideck structure and for the hull supporting structure taking into consideration the material types.

The maximum Von Mises stresses, σ_{VM}, in plate elements and maximum combined stress, σ_c, in the bar elements of the helideck structure are presented in Table 3 and Fig. 5 to Fig. 8.

The maximum Von Mises stresses, σ_{VM}, in plate elements of the hull supporting structure are presented in Table 4 and Fig. 9 to Fig. 12.

Table 3: *Yielding Results – Helideck structure*

	Landing positions	σ_a [MPa]	plates		bars	
			σ_{VM} [MPa]	Figure	σ_c [MPa]	Figure
Landing	A	238	152	Fig. 5	**133**	Fig. 7
	B		159		117	
	C		**168**		106	
	D		138		113	
	E		137		108	
	F		155		107	
Transit	-	284	**182**	Fig. 6	**146**	Fig. 8

Table 4: *Yielding Results – Hull structure*

Load Case		NV-36		NV-32	
		σ_a/σ_{ap} [MPa]	σ_{VM} [MPa]	σ_a/σ_{ap} [MPa]	σ_{VM} [MPa]
Landing	H1	309	236	274	206
	H2		154		138
	H3		153		138
	H4		196		164
	H5		189		163
	S1		**240** Fig. 9		**210** Fig.11
	S2		160		141
	S3		159		140
	S4		205		167
	S5		202		168
Transit	H1	309	**306** Fig.10	274	**271** Fig. 12
	H2		213		191
	H3		210		191
	H4		286		225
	H5		275		224
	S1		291		257
	S2		201		176
	S3		202		176
	S4		254		207
	S5		250		209

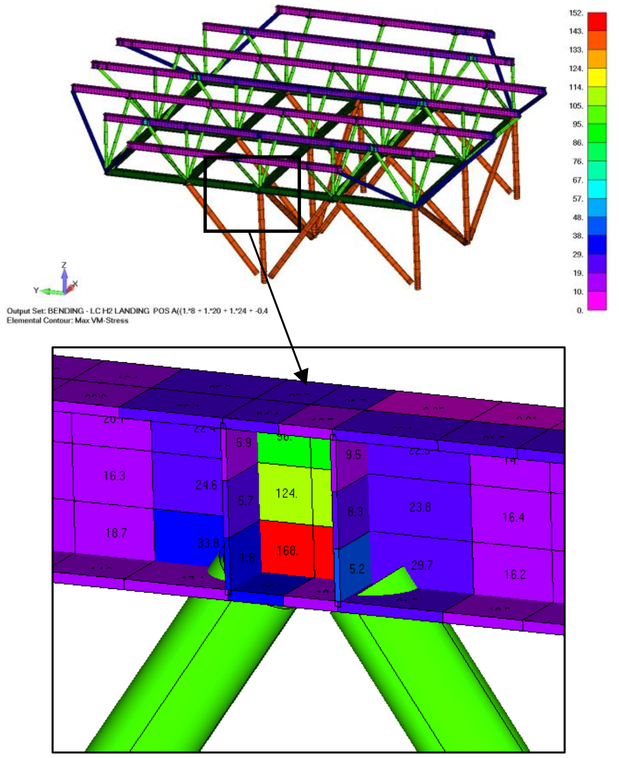

Figure 5: *Helideck structure–Max. Plate VM stress, landing condition*

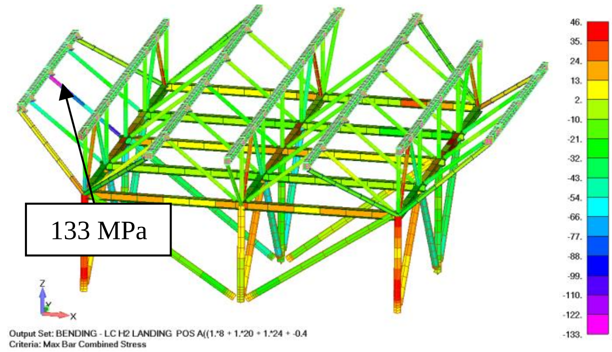

Figure 7: *Helideck structure – Max. bar combined stress, landing condition*

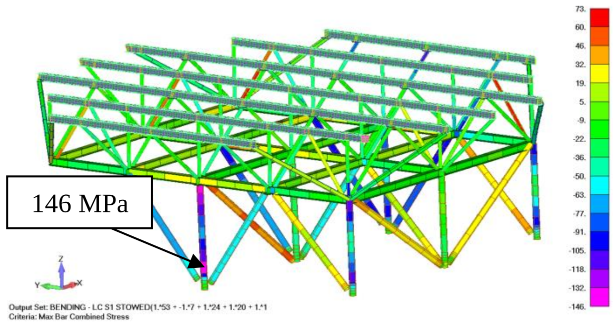

Figure 8: *Helideck structure – Max. bar combined stress, transit condition*

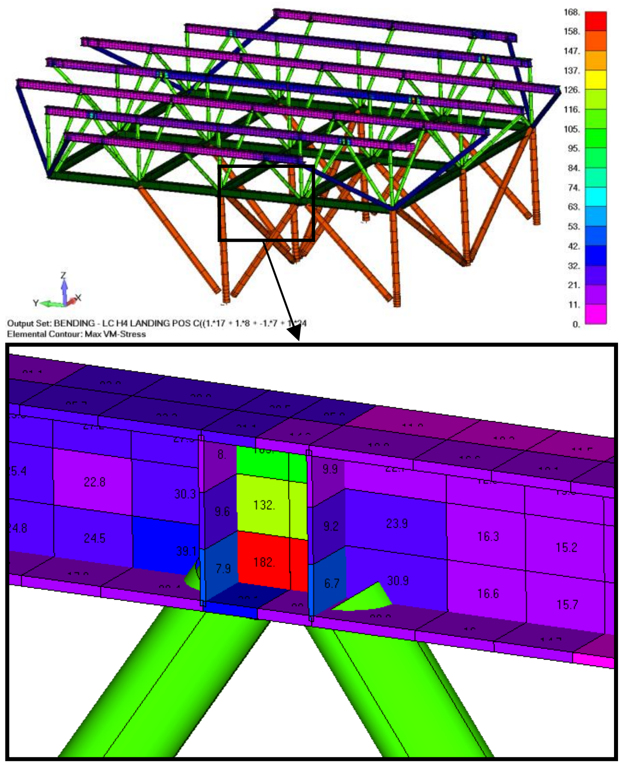

Figure 6: *Helideck structure – Max. Plate VM stress, transit condition*

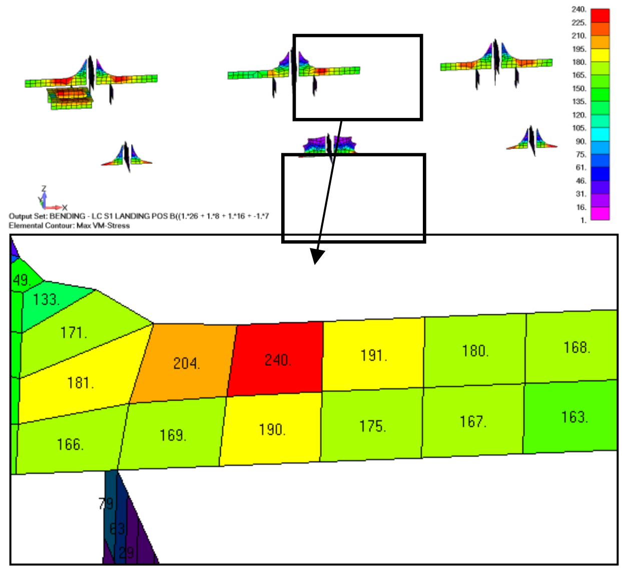

Figure 9: *Hull structure - Max. plate VM stress, landing condition*

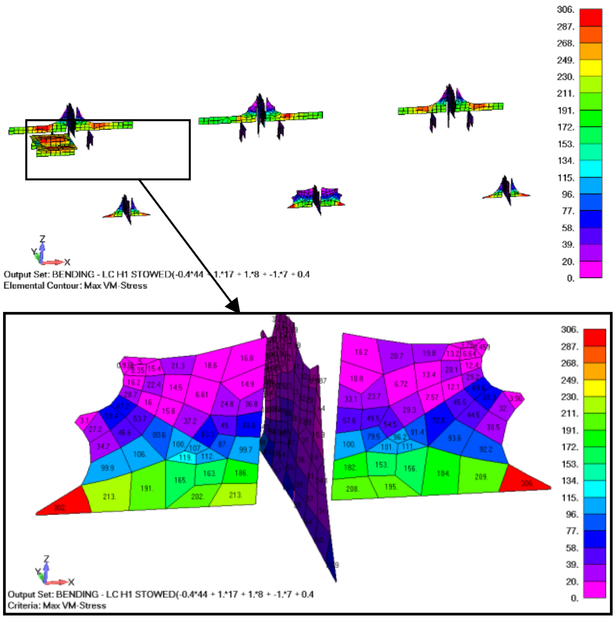

Figure 10: *Hull structure - Max. plate VM stress, transit condition*

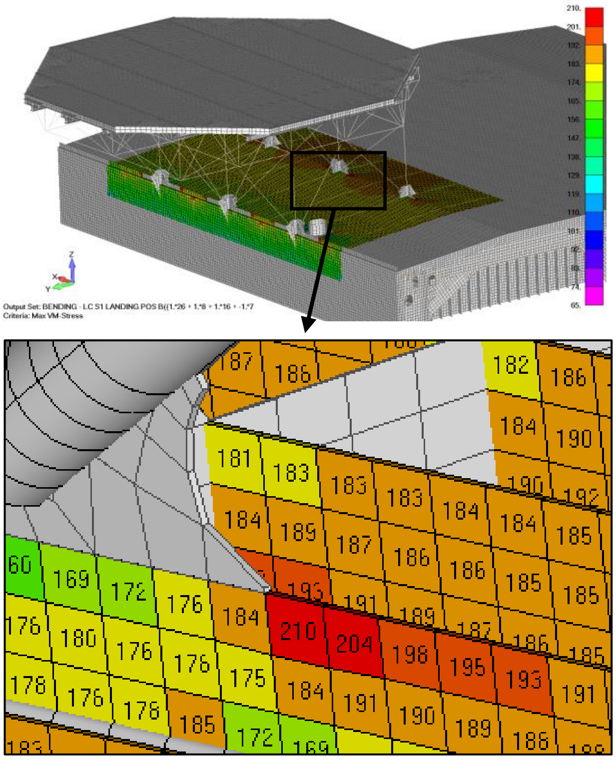

Figure 11: *Hull structure - Max. plate VM stress, landing condition*

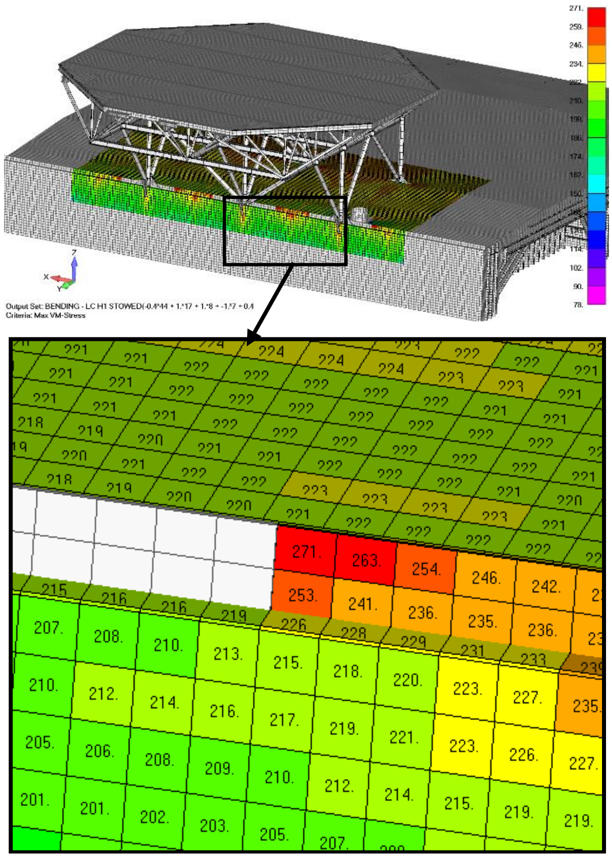

Figure 12: *Hull structure - Max. plate VM stress, transit condition*

4. Conclusions

The scope of this calculation report is to present the yielding check of the helideck supporting structures and their hull interface structure according to classification register rules.

The yielding strength of the helideck and hull interface structure is evaluated by finite elements analysis using the loads and load combinations presented in chapter Model description. The validity of the results is restricted to the assumptions and limitations presented.

In accordance with the calculation results presented in chapter Results, it concluded that the yielding criteria are fulfilled for helideck structure and their hull interface and the additional local reinforcements have been applied to the hull structure.

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