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AN AUTOMATIZED IN-PLACE ANALYSIS OF A HEAVY LIFT JACK-UP VESSEL UNDER SURVIVAL CONDITIONS

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Abstract. *Heavy lift jack-up vessels (HLJV) are used for the installation of components of large offshore wind farms. A systematic FE-analysis is presented for the HLJV THOR (owned by Hochtief Infrastructure GmbH) under extreme weather conditions. A parametric finite element (FE) model and analysis are developed by using ANSYS®[1]-APDL[2] programming environment. The analysis contains static and dynamic nonlinear FE-calculations, which are carried out according to the relevant standards (ISO 19905) for in-place analyses of jack-up vessels. Besides strategies of model abstraction, a guide for the determination of the relevant loads is given. In order to calculate the dynamic loads, single degree of freedom (SDOF) analogy and dynamic nonlinear FE-calculations are used. As a result of detailed determination of dynamic loads and consideration of soil properties by spring elements, the used capacities are able to be reduced by 28 %. This provides for significant improvement of the environmental restrictions of the HLJV THOR for the considered load scenario.*

Key Words: *Heavy Lift Jack-up Vessels, Site-specific Assessment, Drag/Inertia Parameter Method, THOR, Offshore Industry*

1. INTRODUCTION

The ambitious goal of the federal government of Germany of having 25 GW wind energy output installed by 2030 (see [1]) could not be achieved without special heavy tools and machinery like HLJVs. Besides crane capacity of up to 1500 tons, HLJVs are characterized by their jacking system that allows them to elevate their hull above the water surface (see Fig. 1). In this way the hydrodynamic loads are decreased and all loads are transferred into the ground. As a result, the environmental restrictions for this kind of vessels can be increased in comparison with conventional floating installation vessels.

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[1] ANSYS® is a registered trademark of Ansys Inc.

[2] ANSYS Parametric Design Language

Environmental restrictions for operations are described by maximum wave height and wind velocity, which are given in the technical specification of a HLJV (for THOR see [7]). In case these restrictions are exceeded, the vessel has to change into survival mode. In this mode, the crane operations are stopped and it is moved into rest position. If necessary, the safety distance between the hull and the water surface (air gap) is increased. Like in the operating mode, the restrictions are defined for the survival one. If these are exceeded, the vessel has to find shelter in a port or it has to be evacuated. The survival restrictions depend on the ultimate limit state (ULS) of the current system configuration.


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Fig. 1 Hochtief HLJV THOR

The determination of ULS is a challenge due to the complex load situation (see [10]). The loads acting on jacked HLJVs can be classified into three main categories:

1. Deadweight
2. Wind and ocean loads
3. Inertia loads

The determination of these loads is influenced by the configuration of the vessel, its deck load and the operating location. Assumptions have to be made (see [9], [11]) for their calculation and application. It is necessary to create a FE-model, which represents the stiffness and dynamic behavior of the vessel. The stiffness of the leg structure can be assumed as soft, compared to the hull structure. This leads to relatively large deformations and hence the geometric nonlinear effects have to be taken into account (see [14]). The soil properties are always site-specific and present only approximations without detailed soil surveys. This uncertainty has to be considered in the analysis model by choosing appropriate boundary conditions (see [12]) or using a conservative approach like a pinned support.

Under survival conditions the in-place analysis (IPA) is assessed for the extreme storm event. If the critical load headings are unknown, different loads distributed around the circumference directions have to be taken into account. This includes investigating a large number of load cases by using the LRFD-method (Load and Resistance Factor Design).

2. METHODOLOGY

A systematic FE-analysis is presented for the leg structure of the HLJV THOR under survival conditions. In order to carry out an analysis according to the relevant standards, the deterministic two-stage approach is used. In the first stage, an inertia load set is determined, which is calculated either with a single degree of freedom analogy in combination with the total base shear or with more detailed methods like a random wave time domain dynamic analysis. In the case of applying a detailed method, a simplified FE-model is sufficient to calculate the inertia load set. Afterwards the maximums of the environmental loads (wave, current and wind actions) are determined. In the second stage these loads are combined with the inertia load set to find out the response with the detailed structural FE-model including geometrical nonlinear effects in a static analysis. Different load directions are considered, where the combination of actions is applied in phase.

3. FE-MODELS OF HLJV THOR

Two different FE-models are required for the deterministic two-stage approach:

1. Detailed FE-model of the THOR (static analysis)
2. Simplified FE-model of the THOR (dynamic analysis)

The detailed FE-model (see [1]) mainly consists of shell and beam elements. The decks, longitudinal girders, longitudinal bulkheads, transverse frames, bulkheads, tank walls and the outer skin of the vessel are modeled using shell elements. Beam elements are used to model the stringers, deck supports and leg structure. The leg cross sections are modeled as areas and then implemented as cross-sections in ANSYS. The hull-leg-connection is realized by an analogous model consisting of link and spring elements (see Fig.). The simplified FE-model (see Fig.) consists of beam and pipe elements and is used for the dynamic analysis in irregular sea states. The hull-leg-connection is realized by an analogous model consisting of spring elements.

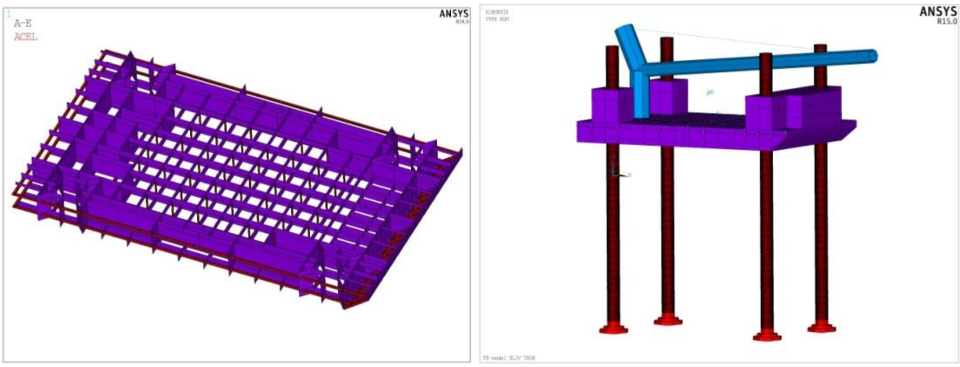


Fig. 2 Detailed FE-model of HLJV THOR

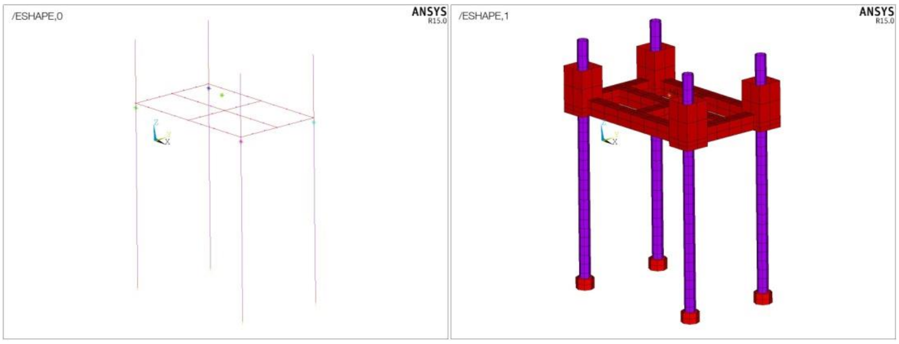


Fig. 3 Simplified FE-model of HLJV THOR

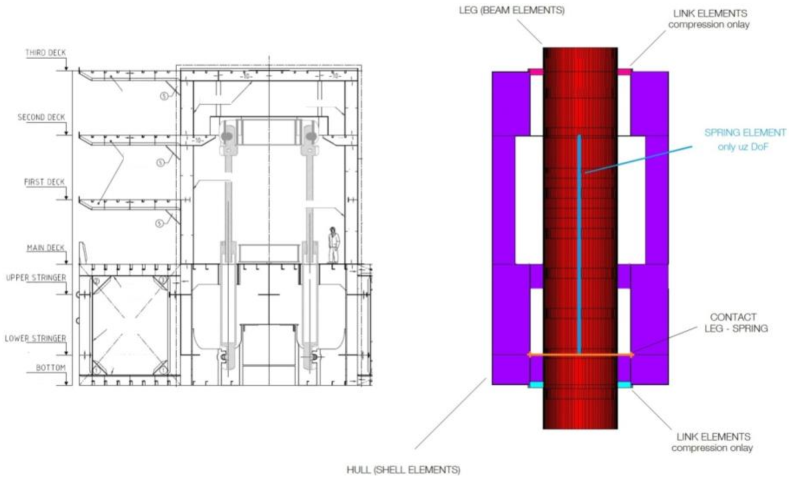


Fig. 4 Hull-leg connection (detailed FE-model)

Soil properties are considered through nonlinear spring elements. The nonlinear load-displacement relationship for vertical, horizontal forces and overturning moment is described by a hyperbolic curve, which is defined according to [14]. If soil parameters are unknown, the interaction between soil and structure should be assumed as a pinned support. The generation of the FE-model is parameterized by using the ANSYS-APDL programming environment so that all the necessary configurations including the choice of boundary conditions can be created.

4. EIGENVALUE ANALYSIS

In order to characterize the basic dynamic system behavior an eigenvalue analysis is performed. The resulting natural frequencies and mode shapes, which are functions of the structural properties and boundary conditions, allow an evaluation of the system regarding stiffness and mass distribution. Furthermore, these values are used to adjust the properties of the simplified model. To evaluate the influence of the soil in the eigenvalue analysis, the resulting natural periods for the following boundary conditions are determined:

Table 1 Natural periods of investigated variants

No.	Variants	Normalized natural periods [s]		
		1.	2.	3.
1	Pinned support	1.00	0.97	0.71
2	Spring support	0.67	0.66	0.48
3	Spring support (pre-stressed)	0.72	0.71	0.50

The natural periods for the listed variants in Tab. 1 are normalized by dividing the values by the first natural period of the first variant (pinned support). Additionally, the natural periods are used for the determination of excitation periods within the structural dynamic analysis. The first two mode shapes of jacked HLJVs are usually the displacements of the hull in longitudinal and the transverse direction (see Fig. 5).

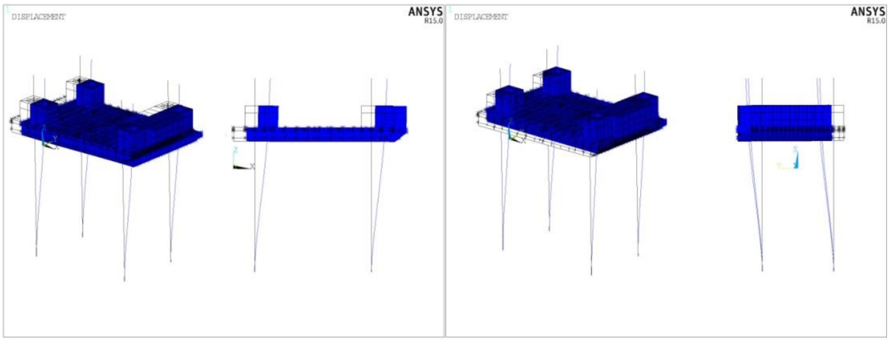


Fig. 5 First and second mode shape of jacked HLJV THOR

The maximum difference between the variants 1 and 2 of the first natural period is 33 % (see Tab. 1), which shows a large influence of the kind of support. The influence of pre-stress has a maximum value of 7 % for the considered load scenario (see Tab. 2).

5. LOADS AND THEIR APPLICATION

All relevant loads are calculated in the developed APDL macros. In the following, the used load assumptions and corresponding macro descriptions are given.

5.1 Deadweight

The deadweight of the HLJV can be roughly divided into two groups, permanent and variable masses. The permanent masses are taken into account by means of the modeled structure elements and an assigned density. The variable masses such as cargo, ballast and equipment are taken into account by a single point mass connected to the hull structure. Its location and mass are calculated by using the center of gravity principle (Eqs. (1) and (2)):

$$x_i = \frac{x_{i,trg} m_{trg} .x_{i,actual} m_{actual}}{m_{trg} - m_{actual}} , \tag{1}$$

$$m_{corr} = m_{trg} - m_{actual} , \tag{2}$$

where x_{actual}, x_{trg} and m_{actual}, m_{trg} are the actual and target coordinates and masses.

5.2 Ocean loads

The legs of HLJV THOR are idealized as slender cylinders. The hydrodynamic loads on submerged line elements are calculated by using the Morison equation for moving bodies (according to [5]):

$$\frac{F}{L} = \rho_w A \ a_{rel} + \rho_w C_a A \ a_{rel} + 0.5 \rho_w C_d D \,|\, v_{rel} \,|\, v_{rel} , \tag{3}$$

where C_a is the added mass coefficient, C_d is the drag coefficient, ρ_w is the water density, D is the cylinder diameter, A is the cylinder cross section area, and v_{rel} and a_{rel} are relative velocities and accelerations between the structure and the water particles. Two different wave theories are used. For regular waves Stokes 5th order wave theory is considered and in the case of random waves the linear wave theory with an empirical modification around the free surface in order to account for free surface effects (Wheeler stretching see [15]) is used.

The equations of motion for a submerged structure can then be expressed as:

$$(M + M_a)\ddot{u} + C\dot{u} + Ku = \rho_w A\ddot{v} + \rho_w C_a A\ddot{v} + 0.5\rho_w C_d D \,|\, (\dot{v} - \dot{u}) \,|\, (\dot{v} - \dot{u}) , \tag{4}$$

with

$$M_a = \rho_w C_a A \ a_p , \tag{5}$$

where M and M_a are the mass and the added mass matrix of the entire structure. Matrix C represents the Damping and K the stiffness matrix and a_p particle acceleration.

The buoyancy force and the hydrostatic pressure on each submerged element are calculated as follows (see [5]):

$$\frac{F}{L} = \frac{C_b \rho_w \pi D^2}{4} \bar{g}; \ \ P_i = -\rho_0 g (Z - Z_0) + P_i^a , \tag{6}$$

$$P_i = -\rho_0 g (Z - Z_0) + P_i^a , \tag{7}$$

Where P_i and P_i^a are the inner and outer tube pressure, Z_0 is the z-coordinate of the water surface, $\bar{g}$ is the acceleration vector and C_b is the buoyancy coefficient.

Ocean loads include the effects of waves, current, drag, and buoyancy. They are taken into account by the definition of an ocean environment in ANSYS.

In the static analysis of the deterministic two stage approach, the sea state during a storm event is represented by regular waves defined by wave height H_{max} and wave period T_P. For each wave angle of attack, the wave travelling through the structure is simulated with 72 time-steps/period. For every considered time-step, the acting wave loads and the total base shear (TBS) are determined by static calculation and subsequently saved in an array.

In the random wave time domain dynamic analysis the wave elevation is modeled as linear random superposition of the regular wave. The sea state is defined by increased significant wave height H_S (H_{spr} is the significant wave height) and peak period T_P using an appropriate spectrum (see section 6). The considered significant wave height is calculated according to [4] and the peak period is calculated according to [3] (see Eqs. 8, 9 and 10):

$$H_{spr} = H_{\max} / 1.86 \,, \tag{8}$$

$$H_s = [1 + 0.5 \cdot \exp(-d/25)] H_{spr} \,, \tag{9}$$

$$T_P = 3.6\sqrt{H_{spr}} \,, \tag{10}$$

where d is the water depth. The created sea states are to be checked within the limits of the theoretical targets for the mean, standard deviation, skewness and kurtosis according to [4]. If all criteria are fulfilled, the current seed number is saved for further use. This allows reproducing the statistically representative sea state at any time.

5.3. Wind loads

Wind forces and pressures on members above the sea surface are considered as steady loads. The wind force component acting normal to the member axis or surface is calculated with the following equation:

$$F_{wi} = P_i A_{wi} = 0.5 \rho_{air} {v_{ref}}^2 C_h C_s A_{wi} \,, \tag{11}$$

where C_h and C_s are the height and shape coefficients, v_{ref} is the reference wind velocity, A_{wi} is the windage area of a structural component and ρ_{air} is the air density. The wind loads are automatically calculated by an APDL macro. The macro determines the resulting wind loads for any configuration of the parameterized FE-model for each considered load direction Θ. Height coefficient C_h is calculated according to [8] with an idealized profile model representing the variation of mean wind speed as a function of the height above the still water level. The windage areas are determined with a surface model developed especially for the calculation of wind forces (see Fig. 6.). The created windage areas are divided into stripes (see Fig. 7, left). The wind loads on each stripe are calculated and combined to resulting force $F_w(\Theta)$.

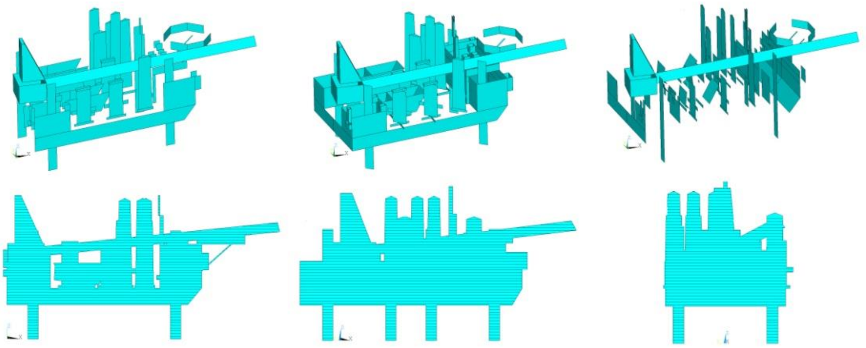


Fig. 6 Surface model for the calculation of windage areas

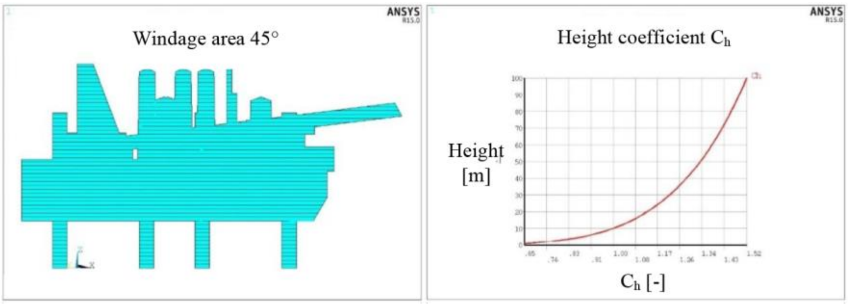


Fig. 7 Windage area for wind heading of 45° (left); height coefficient profile (right)

5.4. Inertia loads

For the determination of the inertia loads two methods were implemented:

1. Single degree of freedom (SDOF) analogy in combination with the amplitude of TBS Q_A (see Eq. 12)
2. Random wave time domain dynamic analysis (detailed method)

The SDOF analogy is permissible for factored (see Eq. 12) values of $1 > \Omega_{fac} > 0.5$.

$$\Omega_{fac} = \frac{T_N}{T_W} = \frac{\text{Natural period}}{0.9 \cdot \text{Excitation period}}, \tag{12}$$

For excitation periods near the resonance range or for critical load cases with small Ω-values (0.5-0.7), it is necessary to use a more detailed method like the random wave time domain dynamic analysis.

5.4.1. Inertia load set based on a single degree of freedom analogy

For a single degree of freedom system the dynamic amplification factor (DAF) is:

$$DAF = \frac{1}{\sqrt{(1-\Omega^2)^2 + (2\xi\Omega)^2}}, \tag{13}$$

For excitation periods in the resonance range a maximum DAF (DAF_{DNV} see Eq. 15) based on a parametric study, described in [8], is used.

$$\xi_{ST} = 0.75 \cdot \xi^{0.65}, \tag{14}$$

$$DAF_{DNV} = \frac{1}{2\xi_{ST}}, \tag{15}$$

Inertia load $F_I(\Theta)$ is determined as given in Eq. 16 for all considered load directions:

$$Q_A(\Theta) = \frac{TBS_{\max}(\Theta) - TBS_{\min}(\Theta)}{2}, \tag{16}$$

$$F_{I,SDOF}(\Theta) = (DAF - 1) \cdot Q_A(\Theta), \tag{17}$$

As recommended in [4], this load is applied at the COG of the hull structure.

5.4.2 Inertia load set based on random wave time domain dynamic analysis

The dynamic nonlinear response of the structure is not a Gaussian process. For this reason the prediction of the most probable maximum extreme (mpme) value of the response during an extreme storm event needs specific probabilistic models. In order to estimate these values, the drag inertia parameter method is used. In the drag inertia parameter method the maximum value of the dynamic response (mpm_D) is expressed as a quasi-static part, an inertia part and an appropriate correlation factor (see Eq. 18).

$$mpm_D{}^2 = mpm_I{}^2 + mpm_S{}^2 + 2\rho_R \cdot mpm_I \cdot mpm_S\,, \tag{18}$$

The correlation factor ρ_R is defined as:

$$\rho_R = \frac{\sigma_{RD}{}^2 - \sigma_{RI}{}^2 - \sigma_{RS}{}^2}{2\sigma_{RI}\sigma_{RS}}\,, \tag{19}$$

Where σ_{RS}, σ_{RI} and σ_{RD} are the standard deviations of the static, inertia and dynamic response. The mpme value of the dynamic response ($mpme_{RD}$) is calculated with the mean value of the dynamic response (μ_{RD}) and the maximum value of dynamic response:

$$mpme_{RD} = \mu_{RD} +, mpm_D\,, \tag{20}$$

The most probable maximum extreme value of the static response is determined (see Eq. 21) using probability factor C_{RS}, standard deviation σ_{RS}, and the mean value of static response μ_{RS}.

$$mpme_{RS} = \mu_{RS} + C_{RS} \cdot \sigma_{RS}\,, \tag{21}$$

Probability factor C_{RS} is calculated according to [4] with the:

- Standard deviation of the static response with a totally drag dominated Morison force [$\sigma_{RS}(C_m=0)$]
- Standard deviation of the static response with a totally inertia dominated Morison force [$\sigma_{RS}(C_d=0)$]

$$C_{RS} = \sqrt{\frac{[8 \cdot \sigma_{RS}(C_m = 0)]^2 + [3.7 \cdot \sigma_{RS}(C_d = 0)]^2}{[8 \cdot \sigma_{RS}(C_m = 0) + 3.7 \cdot \sigma_{RS}(C_d = 0)]^2}}\,, \tag{22}$$

The inertia $mpme_{RI}$ is then estimated by the difference between the calculated mpme values for TBS and the overturning moment (OTM).

$$mpme_{RI} = mpme_{RD} - mpme_{RS}\,, \tag{23}$$

The inertia load set consists of:

$$F_I = mpme_{I,TBS}\,, \tag{24}$$

$$M_I = mpme_{I,OTM}\,, \tag{25}$$

Inertia force F_I is applied at a location in the horizontal COG of the HLJV but at an elevation z_I to fulfill the resulting overturning moment value. Because large deformations are taken into account, the resulting overturning moment is greater than the calculated one (see Eq.

25) due to the displacement of the COG. By using z_I elevation the overturning moment will be overestimated.

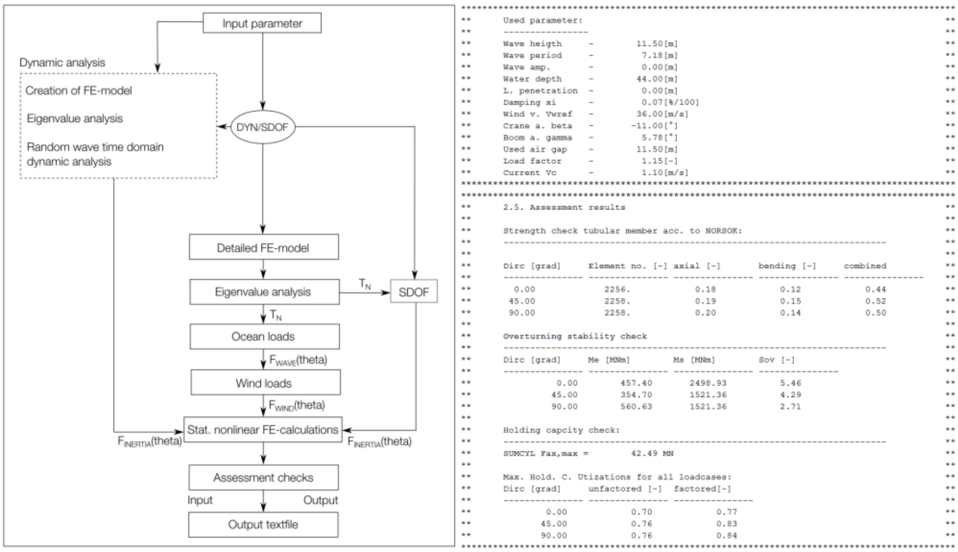
For the dynamic FE-calculations, the simplified FE-model of HLJV THOR (see Section 2) is used. According to [2] a maximum critical damping of 7 % is adopted. Hydrodynamic damping (2% - 3%) is considered by the application of the Morison equation in combination with taking large deformation into account. The structural and soil damping is included by a proportional damping (Rayleigh damping). For this purpose, the coefficients α (mass damping) and β (stiffness damping) are calculated assuming a constant critical damping for the frequency range between the first and second natural frequency.

6. APDL ROUTINE

The above explained approach for the determination of all relevant loads and the creation of both FE-models were implemented in the developed APDL routine. In addition, all listed assessment checks according to their relevant standards were implemented:

1. Structural assessment check according to NORSOK [6]
2. Overturning stability check according to [2]
3. Holding capacities check [2]

Fig 8 (left) shows a flowchart of the created routine. The input, as well as the output is summarized as a text file in ASCII format (see Fig. 8, right). The input parameters can be set in any conventional editor.



```
***********************************************************************************************
**      Used parameter:                                                                      **
**      ----------------                                                                     **
**      Wave heigth      -        11.50[m]                                                   **
**      Wave period      -         7.18[m]                                                   **
**      Wave amp.        -         0.00[m]                                                   **
**      Water depth      -        44.00[m]                                                   **
**      L. penetration   -         0.00[m]                                                   **
**      Damping xi       -         0.07[%/100]                                               **
**      Wind v. Vwref    -        36.00[m/s]                                                 **
**      Crane a. beta    -       -11.00[°]                                                   **
**      Boom a. gamma    -         5.78[°]                                                   **
**      Used air gap     -        11.50[m]                                                   **
**      Load factor      -         1.15[-]                                                   **
**      Current Vc       -         1.10[m/s]                                                 **
***********************************************************************************************
***********************************************************************************************
**      2.5. Assessment results                                                              **
**                                                                                           **
**      Strength check tubular member acc. to NORSOK:                                        **
**      -------------------------------------------------------------------------            **
**                                                                                           **
**      Dirc [grad]     Element no. [-] axial [-]       bending [-]     combined             **
**      --------------- --------------- --------------- --------------- ---------------      **
**        0.00             2256.             0.18            0.12            0.44            **
**       45.00             2258.             0.19            0.15            0.52            **
**       90.00             2258.             0.20            0.14            0.50            **
**                                                                                           **
**      Overturning stability check                                                          **
**      -------------------------------------------------------------------------            **
**      Dirc [grad]     Me [MNm]        Ms [MNm]         Sov [-]                             **
**      --------------- --------------- --------------- ---------------                      **
**                 0.00        457.40       2498.93          5.46                            **
**                45.00        354.70       1521.36          4.29                            **
**                90.00        560.63       1521.36          2.71                            **
**                                                                                           **
**      Holding capcity check:                                                               **
**      -------------------------------------------------------------------------            **
**      SUMCYL Fax,max =        42.49 MN                                                     **
**                                                                                           **
**      Max. Hold. C. Utizations for all loadcases:                                          **
**      Dirc [grad]     unfactored [-]  factored[-]                                          **
**      --------------- --------------- ---------------                                      **
**               0.00            0.70            0.77                                        **
**              45.00            0.76            0.83                                        **
**              90.00            0.76            0.84                                        **
***********************************************************************************************
```

Fig. 8 APDL routine (left); Output text file (some parts) analysis 1 (right)

Application example

The following table shows the site specific conditions for the investigated case.

Table 2 Considered load scenario – site specific parameters

Description	Value
Displacement	13500 t
COG[3]	35.00 m / 00.00 m / 14.50 m
Water depth	41.00 m
Leg penetration	3.00 m
Air gap	12.50 m
Initial spring stiffnesses[4]	K_h = 1340 MN; K_v = 1580 MN; K_{rot} = 19200 MNm

The investigation consists of two analyses:

1. Detailed: Dynamic FE-calculations are carried out to determine the inertia load set. The structure is fixed at the bottom using springs with nonlinear stiffness curves, which describe the soil mechanical properties.
2. Conservative: The SDOF method is used to calculate the inertia load set, and the structure is fixed at the bottom with a pinned support.

All partial safety factors are set according to [2]. In both analyses 3 load directions are considered, 0°, 45° and 90°.

Ocean loads

A maximum surface current speed of 1.1 m/s and a constant current profile are adopted. The considered maximum wave height H_{max} is equal to 11.5 m. As a conservative approach, the nearest possible wave period to the structure resonance is considered. For the current configuration the wave excitation period will always be greater than the natural period of the structure. As a result, minimum possible wave period T_{min} based on steepness criteria gives the most critical period regarding dynamic amplification. The limiting steepness value S of 1/7 (see Eq. 26), in combination with maximum considered wave height H_{max} and gravitational acceleration g, allows to calculate wave period T_{min} (Eq. 27).

$$S_{\max} = 2\pi \frac{H_{\max}}{g T_{\min}^{2}} = 1/7\,, \tag{26}$$

$$T_{\min} = \sqrt{\frac{2\pi \cdot H_{\max}}{g \cdot S_{\max}}} = 7.18\ \ s\,, \tag{27}$$

The following figure is an illustration of the resulting ocean loads for Θ equal to 0°.

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[3] Basis ship coordinate system

[4] Rounded Hochtief project values

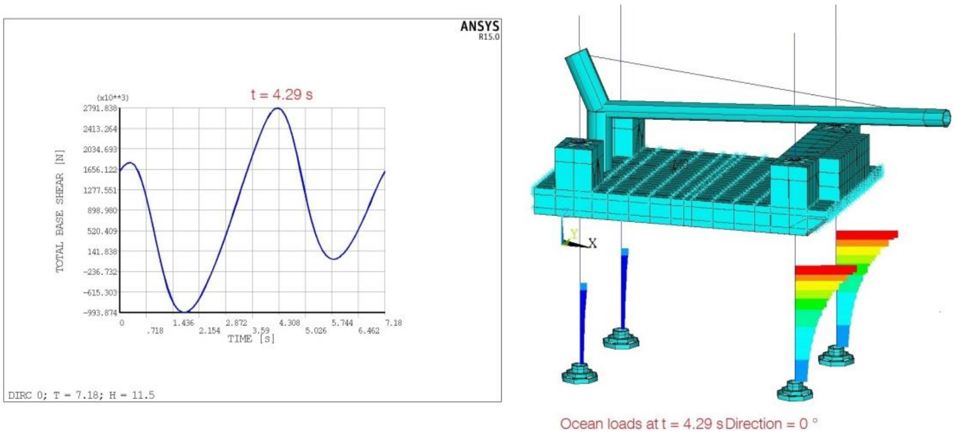

Fig. 9 TBS (left) und $F_{wave}(\Theta)$ (right); $t = 4.29$ s and $\Theta = 0°$

The maximum and minimum TBS values and the resulting Q_A-values are listed in Tab 3.

Table 3 TBS values for all considered load directions

Direction [°]	TBS$_{min}$ [MN]	TBS$_{max}$ [MN]	Q$_A$[MN]
0	–0.99	2.79	1.89
45	–0.38	1.92	1.15
90	–2.06	3.85	2.96

Wind loads

A maximum reference wind velocity of 36 m/s at 10 m above the water surface is adopted. The resulting wind loads and areas are listed in the following table.

Table 4 Calculated wind loads

Direction [°]	F$_w$ [MN]	A$_w$ [m²]
0	1.41	1369
45	2.51	2460
90	2.10	2043

Inertia loads

For the time domain random wave analysis a random sea is simulated over 1 hour for environmental headings at 45-degree intervals from 0 to 90 degrees. The sea state (see Fig. 10, left) is defined by the increased significant wave height H_S equal to 6.75 m and a peak period T_P of 8.98 s using the JONSWAP spectrum. The size of the used time step is $\Delta t = T_N/20$. The dynamic (blue) and static (purple) response signal of TBS (right) is illustrated in the following figure (for heading 0°).

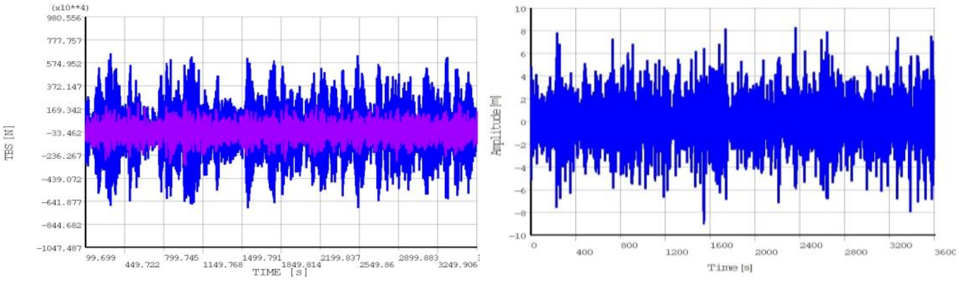

Fig. 10 Statistically representative sea state (3600 s), dynamic and static TBS response signal of the random wave analysis

The resulting inertia loads calculated by the time domain random wave analysis (analysis 1) and SDOF-method (analysis 2) are listed in the following table.

Table 5 Inertia load set for analyses 1 and 2

Analysis	Dir. [°]	F_I [MN]	Method [–]	Boundary conditions [–]
1	0.0	3.98	DI	3
	45.0	1.05	DI	3
	90.0	1.46	DI	3
2	0.0	5.21	SDOF	1
	45.0	3.18	SDOF	1
	90.0	8.15	SDOF	1

Assessment checks results

The calculated utilizations are presented in the following table.

Table 6 Assessment checks two stage analysis - H_{max} = 11.5 m

Ana. no. [–]	Leg pen. [m]	Air gap [m]	Hmax [m]	T [s]	Leg strength check[–]	Holding capacity [–]	Overturning stability [–]
1	3	12	11.5	7.18	0.52	0.84	2.71
2	3	12	11.5	7.18	1.12	1.17	1.35
Differences of utilizations					53.6	28.2	50.2

The calculated used capacity of HLJV THOR in analysis 1 is less than 1.0. Thus the assessment checks satisfy the followed standards requirements (see [2] and [6]). The second analysis only fulfills the requirement of safety against overturning. Both analyses are [2] compliant but are of different computational effort. The first analysis consumes a multiple of computational time compared to the second one. The second analysis using simplified approaches can be carried out within hours, the first analysis within days.

7. CONCLUSION

Site specific IPAs are needed for HLJVs as each location offers new conditions. The created APDL routine allows carrying out of these assessments in a fast and consistent way. The different options, regarding boundary conditions and the determination of the inertia load set enable the user to choose the level of detail. IPAs of non-critical load cases can be performed resource-efficient with the SDOF method. It is easy to implement but it represents only a rough approximation and it does not necessarily lead to conservative results. For critical load cases the implemented drag inertia parameter method offers the possibility to investigate the dynamic behavior according to its irregular nature, in irregular sea state with and achieving a higher accuracy.

By taking soil conditions into account (spring support) and performing a time domain random wave analysis (drag inertia parameter method) the used capacities are reduced by 28 % compared to simplified analysis with SDOF-method and pinned support. The calculated reserves can be used to increase the environmental restrictions and thus to achieve a higher working capacity of HLJV THOR. In order to advance the workability of HLJV THOR parameter studies based on the created script can be performed to estimate the possible range of conditions. The presented assumptions and implemented strategies of load calculations are in accordance with the relevant standards and generally valid.

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AUTOMATIZOVANA ANALIZA NA LOKACIJI BRODSKE DIZALICE ZA TEŠKE TERETE U USLOVIMA OPSTANKA

Brodovi-dizalice za prevoz teških tereta (HLJV) koriste se za instaliranje komponenti velikih offshore *farmi vetrova. U radu prikazujemo sistematsku FE analizu za HLJV THOR (vlasništvo Hochtief Infrastructure GmbH) pod ekstremnim vremenskim uslovima. Model i analiza parametričnih konačnih elemeneta su razvijeni korišćenjem programskog okruženja ANSYS®-APDL. Analiza sadrži statičke i dinamičke nelinearne FE proračune izvršene prema značajnim standardima (ISO 19905) za lokacijske analize brodova-dizalica. Pored strategije apstrakcije modela, date su i smernice za određenje značajnih tereta. Za izračunavanje dinamičkih opterećenja, korišćena je analogija sa jednim stepenom slobode (SDOF) kao i dinamički nelinearni FE proračuni. Kao rezultat detaljnog određenja dinamičkih opterećenja i razmatranja karakteristika tla opružnim elementima, korišćeni kapaciteti su se mogli smanjiti za 28%. Time smo obezbedili značajno poboljšanje sredinskih ograničenja za HLJV THOR za razmatrani scenario opterećenja.*

Ključne reči: *brodovi-dizalice za prevoz teških tereta, procene za specifičnu lokaciju, metoda parametra vuče/inercije, THOR, offshore industrija*