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APPLICATION OF THE RULES OF THE AMERICAN BUREAU OF SHIPPING (ABS) TO DESIGN MOBILE OFFSHORE STRUCTURES

ABSTRACT

The article presents the calculations of Cooling Skid units used on oil rigs required by the specific provisions of the classification society American Bureau of Shipping (ABS). Stringent requirements for equipment intended for offshore drilling research relates to the strength of the environmental loads such as wind loads and strength check points in towing and lifting hooks. The article describes how the simulation calculations are carried out to meet the criteria set for by the classification society American Bureau of Shipping (ABS).

Key words:
Cooling Skid, offshores, frame, wind load, service temperature, lifting attachments.

INTRODUCTION

The purpose of this article is to present the results of computer-based simulation of a Cooling Skid (fig. 1) loaded with environmental loads. The article presents calculations of Cooling Skid units used on oil rigs, required by the specific provisions of the American Bureau of Shipping (ABS) [1, 2, 3, 4].

Stringent requirements for equipment intended for offshore drilling research relate to environmental loads such as wind loads and strength of check points used for towing and lifting hooks. The article describes how to carry out the simulations

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so that they meet the criteria set by American Bureau of Shipping (ABS). The article includes all the calculation steps.

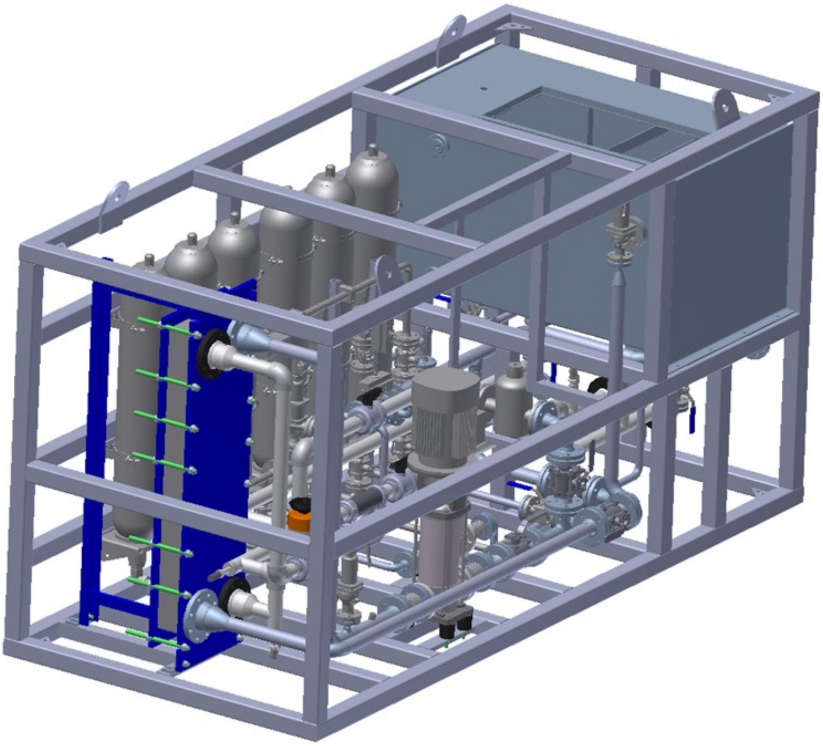

Fig. 1. The 3D main view of the cooling skid unit [own work]

ENVIRONMENTAL LOADS

The unit modes of operation should be investigated using anticipated loads, including gravity and functional loads together with relevant environmental loads related to the effects of wind, waves, currents, and where deemed necessary for the owner or designer, to the effects of earthquake, sea bed supporting capabilities, ambient temperature, fouling, ice, etc. Where applicable, the loads indicated herein are to be adhered to for all types of mobile offshore drilling units. The owner is to specify the environmental conditions for which the plans for the unit are to be approved. These design environmental conditions are to be recorded in the Operating Manual [see 1-1-5/1.3i) of the MODU Rules [3].

Referring to [4] Units 3-1-3: Environmental Loads, the calculations take into account a wind load. A wave load and current load were not considered because these calculations, according to the rules [2–4], relate to the support structures of offshore platforms. Wave loads are included in the acceleration load calculations.

The minimum wind velocity for unrestricted offshore service for all normal drilling and transit conditions is not to be less than 36 m/s (70 kn[1]). All units in unrestricted offshore service are to have the capability to withstand a severe storm condition wherein a wind velocity of not less than 51.5 m/s (100 kn) is assumed. In order to comply with a severe storm condition, all units are to show compliance with this requirement at all times or have the capability to change their mode of operation. The steps to be taken to comply with the 51.5 m/s (100 kn) criteria from the 36 m/s (70 kn) criteria are the responsibility of the owner. Units which, due to intended limited service, are not designed to meet the above criteria may be considered for restricted service classification. For any restricted classification, the minimum wind velocity is to be taken at not less than 25.7 m/s (50 kn).

In the calculation of wind pressure *P*, the following equation is to be used and the height is to be subdivided approximately in accordance with the values listed in table 1.

$$P = f V_k^2 C_h C_s \quad \mathrm{N/m^2}, \tag{1}$$

where:

f — air density coefficient $f = \frac{\rho_{\text{air}}}{2} = 0.611 \quad \mathrm{kg/m^3}$;

V_k — wind velocity in m/s;

C_h — height coefficient from table 1;

C_s — shape coefficient from table 2.

Finally, the wind pressure which loads the skid structure under the most severe conditions is:

$$P = 0.611 \cdot 51.5 \cdot 1.5 \cdot 1.8 = 57 \quad \mathrm{N/m^2}. \tag{2}$$

The figures 3–5 present the calculation results of the stress, displacement and safety factor subjected to wind pressure load. All the results relate to the elastic limit of the material structure.

[1] The knot (/nɒt/) is a unit of speed equal to one nautical mile (1.852 km) per hour, approximately 1.151 mph.

Table 1. Values of C_h [4]

Height (Meters)	*Height (Feet)*	C_h
0.0–15.3	0–50	1.00
15.3–30.5	50–100	1.10
30.5–46.0	100–150	1.20
46.0–61.0	150–200	1.30
61.0–76.0	200–250	1.37
76.0–91.5	250–300	1.43
91.5–106.5	300–350	1.48
106.5–122.0	350–400	1.52
122.0–137.0	400–450	1.56
137.0–152.5	450–500	1.60
152.5–167.5	500–550	1.63
167.5–183.0	550–600	1.67
183.0–198.0	600–650	1.70
198.0–213.5	650–700	1.72
213.5–228.5	700–750	1.75
228.5–244.0	750–800	1.77
244.0–259.0	800–850	1.79
259.0 and above	850 and above	1.80

The height h in m (ft) is the vertical distance from the design water surface to the center of area A defined in 3-1-3/1.3.3.

Table 2. Values of C_s [4]

Shapes or combinations of shapes which do not readily fall into the specified categories will be subject to special consideration.	
Spherical	0.4
Cylindrical shapes (all sizes)	0.5
Hull (surface type)	1.0
Deck house	1.0
Isolated Structural shapes (cranes, angles, channels, beams, etc.	1.5
Wires	1.2
Under deck areas (smooth surfaces)	1.0
Under deck areas (exposed beams and girders)	1.3
Small parts	1.4
Rig derrick (each face)	1.25

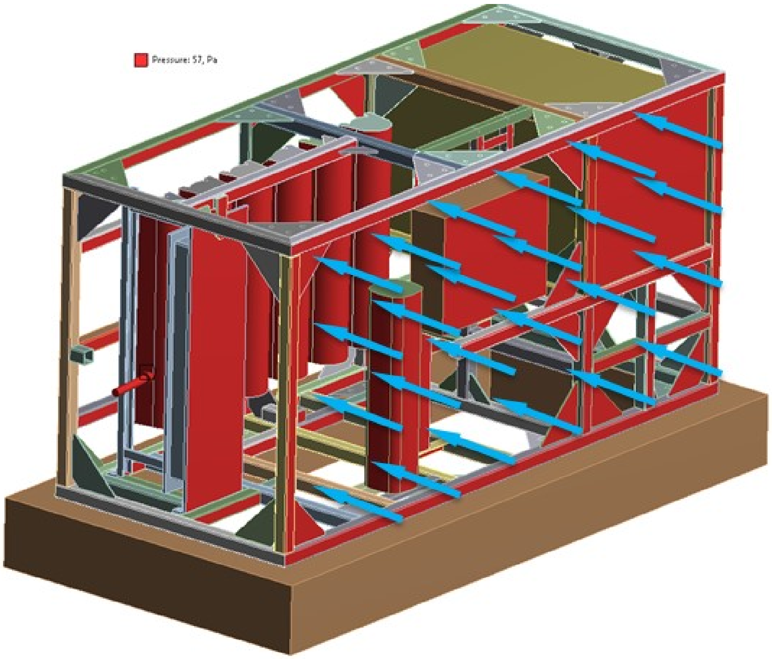

Fig. 2. Applying wind pressure to the cooling skid surfaces [own work]

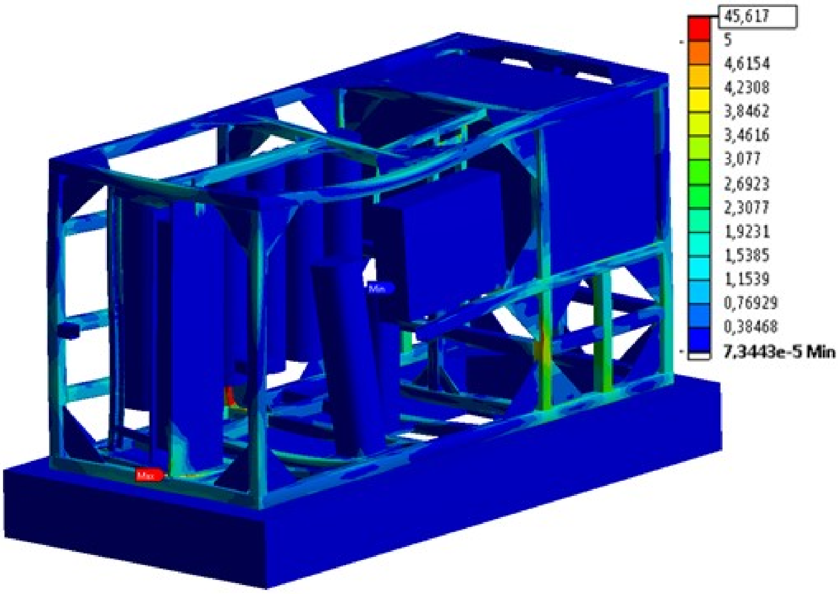

Fig. 3. The equivalent Von Mises stress in MPa; local maximum value 45.6 MPa;
the average nominal value 0.3 MPa — displacement rescaled x 1400 times [own work]

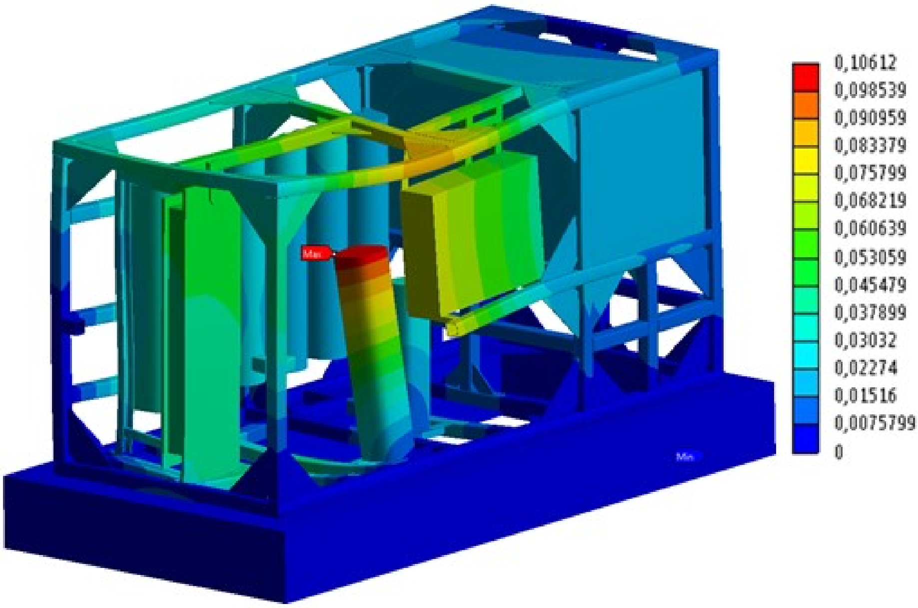

Fig. 4. Result displacement 0.47 mm — displacement rescaled x 1400 times [own work]

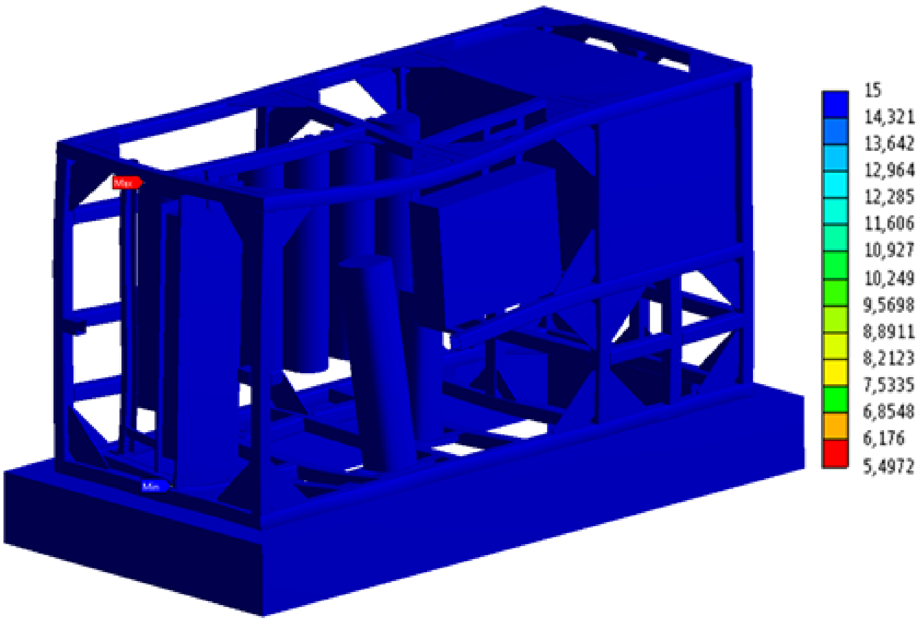

Fig. 5. The minimum safety factor 5.49 — displacement rescaled x 1400 times [own work]

SERVICE TEMPERATURE

Service temperature of a cooling skid made from 316L molybdenum-bearing austenitic stainless steel is in the range –20 to +55°C. Referring to [4] Units 3-1-4: Material Selection: 5.7 Criteria for Other Steels: 5.7.1 General (2012) below (tables 3–6) include appropriate supporting information indicating that the toughness of the steel is adequate to their intended application in the unit structure under the service temperature of the unit.

Table 3. Nominal Mechanical Properties (annealed condition) [own work]

Tensile Strength [MPa]	Yield Strength [MPa]	%Elongation	%Reduction in Area	Hardness HB
550	200	45	55	140

Table 4. Short time elevated temperature tensile properties [own work]

Temperature °C	100	300	500	600	700	800	900	1000	1100
Tensile Strength [MPa]	540	500	480	450	350	205	100	50	25
0.2% Proof Stress [MPa]	235	165	145	140	130	115	–	–	–
Elongation [% in 50 mm]	52	48	47	44	43	42	63	62	76

Table 5. Maximum recommended service temperature (in oxidizing conditions) [own work]

Operating Conditions	Temperature °C
Continuous	920
Intermittent	870

Table 6. Properties at sub-zero temperature [own work]

Temperature °C	20	0	–10	–50	–140	–196
Tensile Strength [MPa]	584	680	832	1105	1136	1360
0.2% Proof Stress [MPa]	235	260	336	380	417	444
Elongation [% in 50 mm]	61	70	69	65	61	58
Impact Energy [J]	170	191	186	183	155	166

LIFTING ATTACHMENTS

[3, 4] particularly Units 3-11-11.5: Lifting equipment, below refer to the appropriate supporting information indicating that the toughness of the lifting points is adequate for lifting by crane, even in cases of possible dynamic overloads as a result of sudden pulls by a tug caused by wind, wave or current load.

The design loads and allowable stresses for lifting attachments used in offshore applications are to be in accordance with requirements of API RP 2A WSD.

Lifting attachments are to be free of stress concentration points. Skid units have to be sufficiently rigid to support the installed equipment and piping so that no damage to the equipment or piping is done during shipment.

The results which are presented in figures 6–10 show that the lifting attachments are streng enough to meet all the American Bureau of Shipping [2–4] requirements.

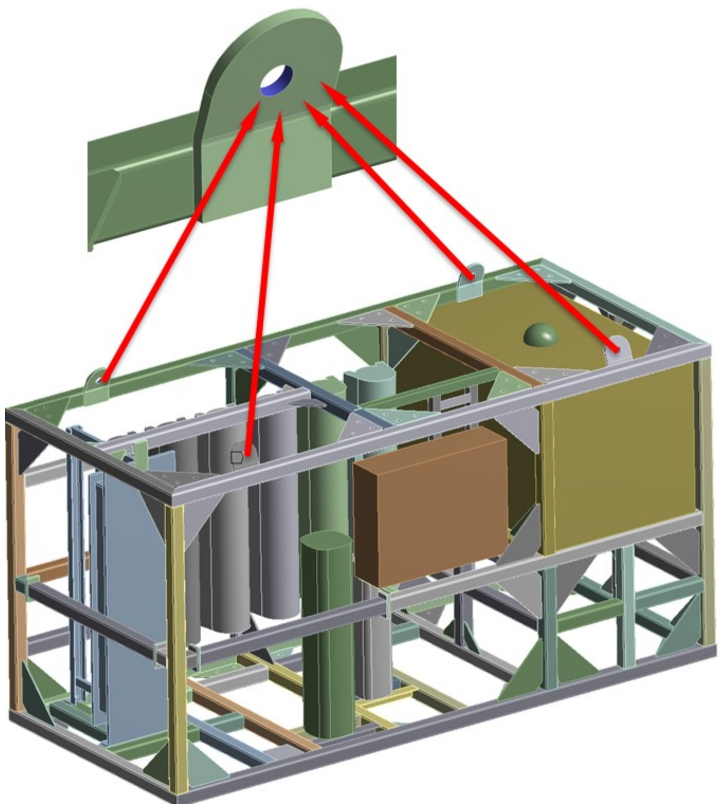

Fig. 6. Cylindrical support points were taken into account as points for suspending ropes [own work]

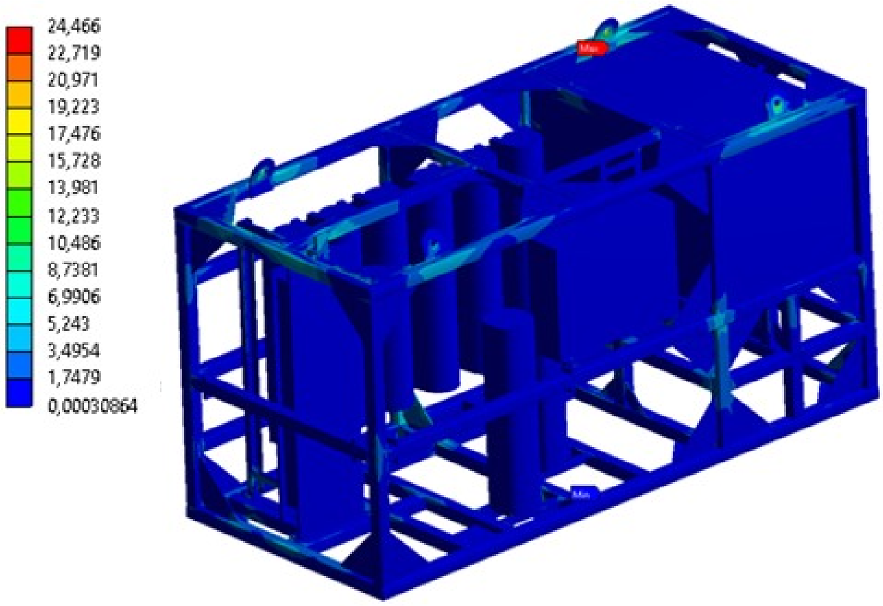

Fig. 7. The equivalent Von Mises stress in MPa; local maximum value 25.8 MPa;
the average nominal value 0.3 MPa — displacement — true scale [own work]

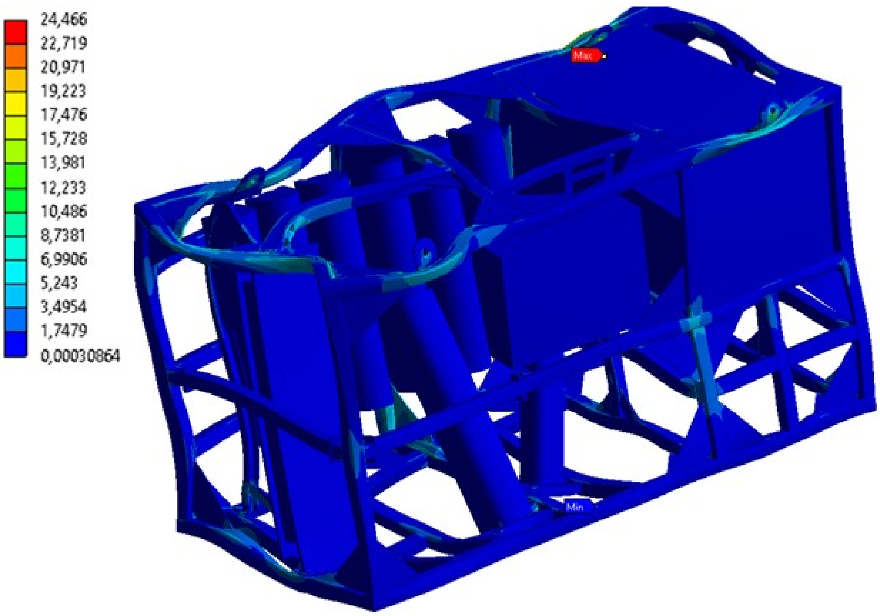

Fig. 8. The equivalent Von Mises stress in MPa; local maximum value 25.8 MPa;
the average nominal value 0.3 MPa — displacement rescaled x 6000 times [own work]

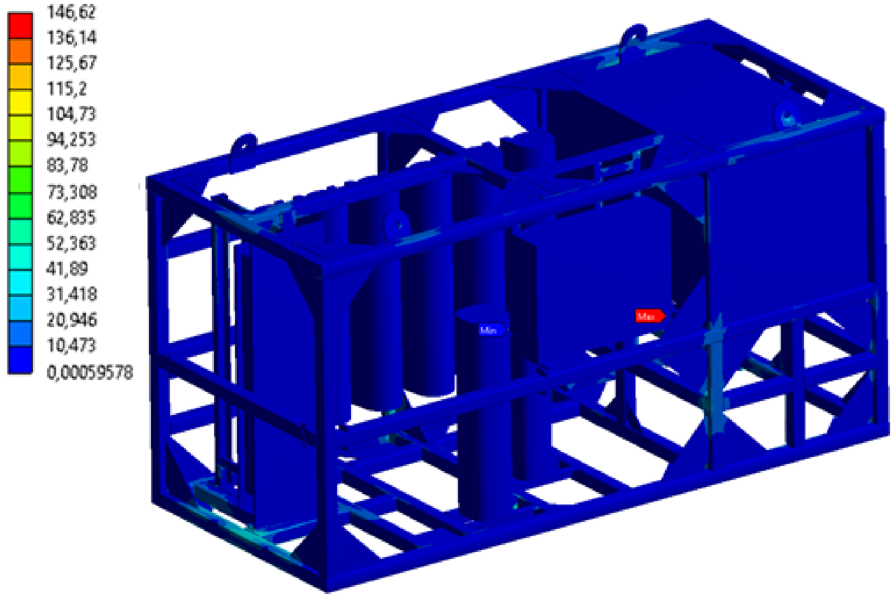

Fig. 9. Mass overload 20% and acceleration overload 4 g; the equivalent Von Mises stress in MPa; local maximum value 146.62 MPa; the average nominal value 5 MPa — displacement — true scal [own work]

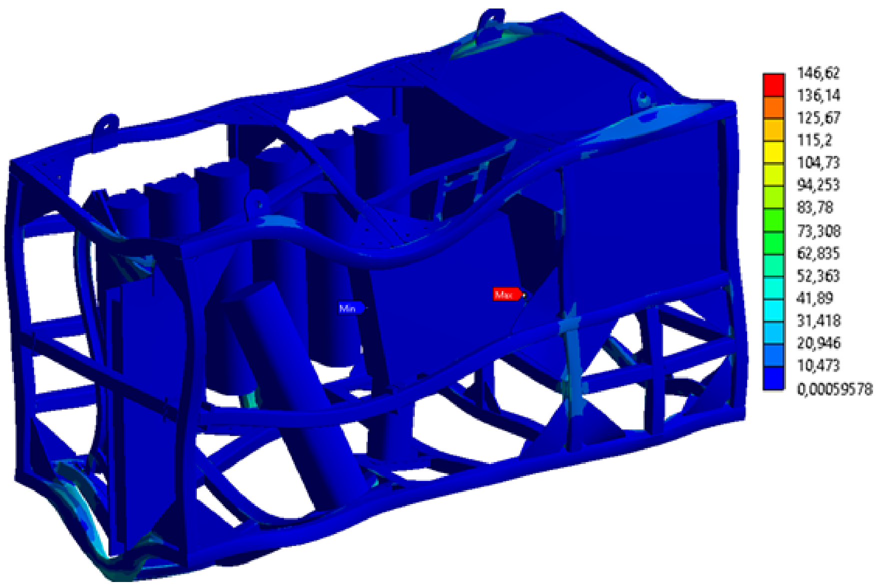

Fig. 10. Mass overload 20% and acceleration overload 4 g; the equivalent Von Mises stress in MPa; local maximum value 146.62 MPa; the average nominal value 5 MPa — displacement rescaled x 1200 times [own work]

CONCLUSIONS

The stresses caused by the wind load in the most severe conditions refer to elastic limit of the material structure.

All strength parameters dependent on the temperature given in tables 3–6 show that calculations for Cooling Skid meet the toughness requirement in the range of service temperature –20 to +55°C and still have a large margin of safety for use event at temperature up to 200°C. In addition, in low-temperature (up to –50°C, in the case of Charpy V-Notch (CVN) impact requirements) tensile strength as well as yield stress limit of the steel increases so the safety temperature range when using the Cooling Skid frame is even broader than –20 to + 55°C.

The stresses caused by loading the lifting attachments are within the range of the elastic limit of the material structure.

Predicting accidental dynamic events like pulls by a tug rope the unit was loaded with the acceleration 10 time higher than the nominal value of up to 40 m/s^2 and the stresses are still within the limit of the material. The cooling skid meets all the requirements set for operating regimes in the ABS rules.

Calculations were carried out at the Academic Computer Centre in Gdańsk.

REFERENCES

[1] *Guide for Certification of Lifting Appliances July 2007* (updated august 2014), American Bureau of Shipping, Incorporated by Act of Legislature of the State of New York 1862.

[2] *Guide for the Classification of Drilling Systems September 2012* (updated February 2014), American Bureau of Shipping, Incorporated by Act of Legislature of the State of New York 1862.

[3] *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms — Working Stress Design*, API Recommended Practice 2a-WSD (RP 2A-WSD), 21 ed., December 2000, errata and supplement 1, December 2002.

[4] *Rules for Building and Classing Mobile Offshore Drilling Units 2015*, Part 3, Hull Construction and Equipment, American Bureau of Shipping, Incorporated by Act of Legislature of the State of New York 1862.

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IMPLEMENTACJA PRZEPISÓW AMERICAN BUREAU OF SHIPPING (ABS) PRZY PROJEKTOWANIU ELEMENTÓW MOBILNYCH WYPOSAŻENIA PLATFORM WIERTNICZYCH

STRESZCZENIE

W artykule przedstawiono obliczenia jednostki Cooling Skid wykorzystywanej na platformach wiertniczych wymagane szczegółowymi przepisami towarzystwa klasyfikacyjnego American Bureau of Shipping (ABS). Surowe wymagania dla urządzeń przeznaczonych na platformy wiertnicze dotyczą badania wytrzymałości konstrukcji na obciążenia środowiskowe, takie jak obciążenia od wiatru oraz sprawdzanie wytrzymałości punktów holowniczych i zaczepów dźwigowych. W artykule wskazano, w jaki sposób realizuje się obliczenia symulacyjne, aby spełniały kryteria towarzystwa klasyfikacyjnego American Bureau of Shipping (ABS).

Słowa kluczowe:

ramy mobilne wyposażenia platform offshore, obciążenie wiatrem, temperaturowe warunki pracy, zaczepy transportowe.