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# Effects of marine growth on jacket structures for the Vietnamese continental shelf condition

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ABSTRACT: Marine growth will potentially increase in structural weight, alteration of the natural period, increase in wave loading and increase in flow instability. Therefore, marine growth will effect on the jacket stresses and the value of dynamic effects of wave loads for jacket structures.

The development of marine growth in the Vietnamese sea is different for each specific sea condition. Currently, jacket design standards of Vietnam have no specific regulations on thickness of marine growth for each sea area. So, analysis jacket structure, we have to use the thickness of the marine growth based on report of the specific environmental conditions of each field.

This paper presents an analysis 03 wellhead platforms (WHP Thai Binh, WHP Thang Long, WHP Dai Hung) with 03 different sea conditions. From that, give some results and recommendations on the influence of marine growth to jacket structure in the specific conditions of Vietnam.

*Keywords*: *Marine growth*, *Effects*, *Jacket*

## 1 INTRODUCTION

Currently, jacket design standards of Vietnam have no specific regulations on thickness of marine growth for each sea area. So, analysis jacket structure, we have to use the estimated thickness of the marine growth based on report of the metocean criteria for the each field. Meanwhile, the data on the actual thickness of marine growth following the recent survey reports in Vietnam is different from the estimated thickness data of the metocean criteria. Specifically see the following data tables.

This paper will analyze the effects of marine growth on the newly constructed jacket structures (WHP Thai Binh, WHP Thang Long, WHP Dai Hung).

## 2 EFFECTS OF MARINE GROWTH ON A JACKET STRUCTURE

Marine growth has number of effects on loading of jacket structure that may among others be listed as the following: (1) increase in structural weight, (2) alteration of the natural period, (3) increase in wave loading, (4) increase in flow instability. In order to see clearly the effect of marine growth to the jacket structure, we consider the single degree of freedom as shown in Figure 1 and these effects are described below.

### 2.1 *Increase in structural weight*

Marine growth will also increase the total weight of the structure. However, the increase is found to be insignificant compared to the total weight of the structure and the variable deck loading. This is due to the low specific gravity of marine growth. [7]

### 2.2 *Alteration of the natural period*

The natural period for a single degree of freedom is given as.

$$T = 2\pi\sqrt{\frac{M}{K}} = 2\pi\sqrt{\frac{M_r + M_a}{K}} = 2\pi\sqrt{\frac{(M_r + M_a)L^3}{EI}} \quad (1)$$

where T is natural period, K is stiffness, $M_r$ and $M_a$ are mass and hydrodynamic added mass of the structure.

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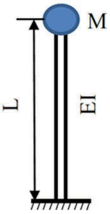



Figure 1. Geometry of the single degree of freedom.

Marine growth will not contribute to the structure stiffness, but represents an increase in the total mass. The increase in displaced volume due to the present of marine growth will increase the mass, $M_r$, and hydrodynamic added mass, $M_a$ of the structure. Thus, marine growth will potentially increase the natural period.

This can be significant for small diameter members and may move the structural response closer to resonance.[7]

## 2.3 *Increase in wave loading*

### 2.3.1 *Increase in diameter*

Estimation of hydrodynamic loading on offshore structure may generally be done using Morison's equation to estimate the hydrodynamic force, F.[2,7]

$$F(t) = \frac{1}{2}\rho C_D D_o |v| v + \rho C_M A \dot{v} \tag{2}$$

where ρ is water density, $C_D$ is drag coefficient, $C_M$ is inertia coefficient, $D_o$ is member's effective diameter (including marine growth), v is water particle velocity in direction of force and $\dot{v}$ is water particle acceleration in direction of force.

Marine growth represents a increase in the diameter $D_o$ and the drag loads on the cylinder will increase. From Equation (2), it can be expected that the force on the cylinder increases linearly with $D_o$ if the drag term dominates and with $D_o$ to the second power if the inertia term dominates.

### 2.3.2 *Increase in force coefficients*

A member's surface will become roughened with the attachment of the fouling organism. The increase in surface roughness gives rise to changes in both the drag and inertia coefficients in Morison's equation. In general the drag coefficient increases with the increase of surface roughness and the inertia coefficient decreases with increasing surface roughness.[2,7]

According to API [1], all structural members, conductors, risers, and appurtenances should be increased in cross-sectional area to account for marine growth thickness. Also, elements with circular cross-sections should be classified as either "smooth" or "rough" depending on the amount of marine growth expected to have accumulated on them at the time of the loading event. For typical design situations, global platform wave forces can be calculated using the following values for unshielded circular cylinders: smooth $C_D$ = 0.65, $C_M$ = 1.6; rough $C_D$ = 1.05, $C_M$ = 1.2.

## 2.4 *Increase in flow instability*

The accumulations of marine growth cause the surface profile become irregular. Marine growth also' increases the size of member's diameter to an effective diameter, $D_o$. This change will affect the formation of vortex shedding that usually occurs at Strouhall number, $S_n >$ of 0.2. [7]

$$S_n = \frac{fD_o}{u} \tag{3}$$

$$F_L = \frac{1}{2}\rho C_L D v|v| \tag{4}$$

where f is vortex shedding frequency, u is flow velocity, $C_L$ is lift coefficient, ρ, v and $D_o$ as previously defined.

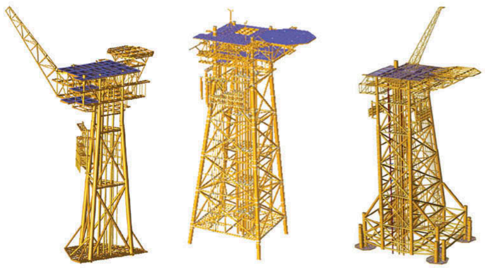
Vortex shedding will not be studied any further in this paper.

# 3 APPLICATION FOR PRACTICAL ANALYSIS

## 3.1 *Input data*

We will analysis the jacket structures WHP Thai Binh, WHP Thang Long and WHP Dai Hung in the Vietnamese continental shelf condition by Sacs software, the main input data are shown in Figure 2 and Tables 5,6,7,8.

For the thickness of marine growth, use the Tables 1,2,3 and Table 4 above.




(a)WHP Thai Binh, (b) WHP Thang Long, (c) WHP Dai Hung

Figure 2. Jacket structure model.

Table 1. Estimated Depth/Thickness Distribution of Marine Growth for Dai Hung field. [5].

| From EL.(LAT) m | To EL.(LAT) m | Thickness mm |
|---|---|---|
| 00 | -1.0 | 27.0 |
| -1.0 | -10.0 | 54.0 |
| -10.0 | -20.0 | 44.0 |
| -20.0 | -30.0 | 50.0 |
| -30.0 | -40.0 | 50.0 |
| -40.0 | -50.0 | 50.0 |
| -50.0 | -75.0 | 50.0 |
| -75.0 | -90.0 | 50.0 |
| -90.0 | -110 (Seabed) | 9.0 |

Table 2. Estimated Depth/Thickness Distribution of Marine Growth for Thai Binh field. [3].

| From MSL m | Thickness mm |
|---|---|
| +0.0 | 90.0 |
| -1.0 | 100.0 |
| -5.0 | 110.0 |
| -10.0 | 100.0 |
| -20.0 | 90.0 |
| -30.0 | 80.0 |

Table 3. Estimated Depth/Thickness Distribution of Marine Growth for Thang Long field. [6].

| From MSL m | Thickness mm |
|---|---|
| MSL | 51.0 |
| -4.60 | 153.0 |
| -48.80 | 102.0 |
| Seabed | 25.0 |

Table 4. Actual Depth/Thickness Distribution of Marine Growth for White Tiger field (2013). [9].

| From EL.(LAT) m | To EL.(LAT) m | Thickness mm |
|---|---|---|
| 00 | -4.0 | 103.2 |
| -4.0 | -8.0 | 103.2 |
| -8.0 | -10.0 | 103.2 |
| -10.0 | -40.0 | 103.2 |
| -40.0 | -50.0 | 60.0 |
| -50.0 | Seabed | 60.0 |

Table 5. Main specifications.

| Main specifications | WHP Thai Binh | WHP Thang Long | WHP Dai Hung |
|---|---|---|---|
| Water depth (m) | 29.2 | 65 | 110 |
| Number of main legs | 03 | 04 | 04 |
| Applied standard | API RP 2A-WSD (2000) | API RP 2A-WSD (2000) | API RP 2A-WSD (2000) |
| Year of design | 2011-2012 | 2010-2011 | 2008-2009 |
| Year completed construction | 2015 | 2013 | 2011 |

### 3.2 *Analysis results*

The outputs in this paper will include: natural period and total wave load for WHP Thai Binh, WHP Thang Long and WHP Dai Hung. The details are shown in Table 9,10,11,12,13,14,15 and Table 17.

### 3.3 *Effect of Marine Growth on the DAF Values*

The DAF values from the approximate equation that is usually used in practice when the jacket first natural period is less than 3.0 sec. The approximate equation is based on the fact that waves has a dominate period ($T_{hmax}$) and the jackets vibrate mainly in the first mode with a period ($T_1$), with a damping ratio ($\xi$) that is usually taken 0.02. [1,4] The approximate equation is given by.

$$\mathrm{DAF} = \frac{1}{\sqrt{\left(1-\Omega^2\right)^2 + (2\xi\Omega)^2}} \tag{5}$$

where $\Omega = \frac{T_1}{T_{h\,max}}$, $T_1$ is the first natural period, $T_{hmax}$ is the waves period, $\xi$ is the damping ratio.

The results of effect of marine growth on the DAF values is shown in Table 16 below.

### 3.4 *Effect of Marine Growth on the wave loading*

Wave load is analyzed with extreme conditions for the dominant wave direction. The wave load given below will be calculated for conditions with and without marine growth. The results are summarized as follows.

where $F_x$ is the total wave load in the X-direction, $F_y$ is the total wave load in the Y-direction, $F_w$ is total wave load in horizontal direction with marine growth, $F_{wo}$ is the total wave load in horizontal direction without marine growth.

Table 6. Wave conditions data for strength analysis of WHP Thai Binh.[3].

| Wave Parameters | As. Wave Directions From N | NE | E | SE | S | SW | W | W |
|---|---|---|---|---|---|---|---|---|
| One - year Return Period | | | | | | | | |
| $H_s$ (m) | 1.51 | 2.68 | 2.56 | 1.64 | 2.05 | 1.34 | 0.16 | 0.66 |
| $T_z$ (s) | 3.6 | 4.7 | 4.6 | 4.3 | 4.8 | 3.9 | 1.2 | 2.5 |
| $T_{hmax}$ (s) | 4.9 | 6.3 | 6.2 | 5.5 | 6.2 | 5.0 | 1.6 | 3.2 |
| $H_{max}$ (m) | 2.97 | 5.54 | 4.99 | 3.19 | 4.01 | 2.62 | 0.32 | 1.30 |
| One Hundred - year Return Period | | | | | | | | |
| $H_s$ (m) | 2.42 | 5.70 | 3.86 | 2.70 | 3.06 | 2.46 | 1.20 | 1.48 |
| $T_z$ (s) | 4.6 | 7.1 | 5.6 | 5.5 | 5.8 | 5.2 | 3.4 | 3.8 |
| $T_{hmax}$ (s) | 6.2 | 9.3 | 7.6 | 7.1 | 7.5 | 6.8 | 4.3 | 4.8 |
| $H_{max}$ (m) | 4.75 | 11.7 | 7.53 | 5.27 | 5.97 | 4.81 | 2.40 | 2.92 |

Table 7. Wave conditions data for strength analysis of WHP Thang Long. [6].

| Wave Parameters | As. Wave Directions From N | NE | E | SE | S | SW | W | W |
|---|---|---|---|---|---|---|---|---|
| One - year Return Period | | | | | | | | |
| $H_s$ (m) | 4.7 | 9.9 | 5.2 | 4.0 | 3.9 | 5.3 | 4.5 | 3.2 |
| $T_z$ (s) | 7.4 | 1.4 | 7.8 | 11.9 | 11.8 | 7.8 | 7.3 | 6.3 |
| $T_{hmax}$ (s) | 2.5 | 5.3 | 2.8 | 2.1 | 2.1 | 2.9 | 2.4 | 1.7 |
| $H_{max}$ (m) | 7.4 | 10.4 | 7.7 | 11.9 | 11.8 | 7.8 | 7.3 | 6.2 |
| One Hundred - year Return Period | | | | | | | | |
| $H_s$ (m) | 7.1 | 14.9 | 7.8 | 6.0 | 5.8 | 8.0 | 6.8 | 4.9 |
| $T_z$ (s) | 8.9 | 12.6 | 9.4 | 13.8 | 13.6 | 9.5 | 8.8 | 7.5 |
| $T_{hmax}$ (s) | 3.8 | 8.0 | 4.2 | 3.2 | 3.1 | 4.3 | 3.7 | 2.6 |
| $H_{max}$ (m) | 8.9 | 12.5 | 9.3 | 13.7 | 13.6 | 9.4 | 8.7 | 7.5 |

Table 8. Wave conditions data for strength analysis of WHP Dai Hung. [5].

| Main specifications | As. Wave Directions From NE | E | SE | S | SW | W | NW | N |
|---|---|---|---|---|---|---|---|---|
| One - year Return Period | | | | | | | | |
| $H_s$ (m) | 8.3 | 4.9 | x | x | 4.7 | 5.6 | x | x |
| $T_z$ (s) | 14.5 | 10.8 | x | x | 10.6 | 11.7 | x | x |
| $H_{max}$ (m) | 13.8 | 7.8 | x | x | 7.5 | 8.9 | x | x |
| $T_{hmax}$ (s) | 11.7 | 9.0 | x | x | 8.8 | 9.6 | x | x |
| One Hundred - year Return Period | | | | | | | | |
| $H_s$ (m) | 10.0 | 5.6 | x | x | 5.7 | 6.9 | x | x |
| $T_z$ (s) | 16.0 | 11.7 | x | x | 11.8 | 13.1 | x | x |
| $H_{max}$ (m) | 16.0 | 9.0 | x | x | 9.1 | 11.0 | x | x |
| $T_{hmax}$ (s) | 12.9 | 9.6 | x | x | 9.7 | 10.7 | x | x |

Table 9. Modal analysis results of WHP Thai Binh with marine growth.

| MODE | FREQ. (CPS) | GEN. MASS | EIGEN-VALUE | PE-RIOD(SECS) |
|---|---|---|---|---|
| 1 | 0.541117 | 2.10E+02 | 8.65E-02 | 1.848028 |
| 2 | 0.858995 | 1.43E+03 | 3.43E-02 | 1.164152 |
| 3 | 0.905295 | 2.26E+02 | 3.09E-02 | 1.104612 |
| 4 | 1.126248 | 1.19E+03 | 2.00E-02 | 0.887904 |
| 5 | 1.156573 | 5.45E+02 | 1.89E-02 | 0.864623 |
| 6 | 1.627879 | 6.47E+02 | 9.56E-03 | 0.614296 |
| 7 | 2.605684 | 3.76E+01 | 3.73E-03 | 0.383776 |
| 8 | 2.854599 | 7.37E+01 | 3.11E-03 | 0.350312 |
| 9 | 3.267869 | 5.10E+00 | 2.37E-03 | 0.306010 |
| 10 | 3.490359 | 1.28E+02 | 2.08E-03 | 0.286504 |

Table 10. Modal analysis results of WHP Thai Binh without marine growth.

| MODE | FREQ. (CPS) | GEN. MASS | EIGEN-VALUE | PE-RIOD(SECS) |
|---|---|---|---|---|
| 1 | 0.556373 | 1.91E+02 | 8.18E-02 | 1.797357 |
| 2 | 0.867089 | 1.31E+03 | 3.37E-02 | 1.153284 |
| 3 | 0.908892 | 2.25E+02 | 3.07E-02 | 1.100241 |
| 4 | 1.285475 | 6.89E+02 | 1.53E-02 | 0.777923 |
| 5 | 1.290240 | 7.61E+02 | 1.52E-02 | 0.775050 |
| 6 | 1.834948 | 4.77E+02 | 7.52E-03 | 0.544975 |
| 7 | 2.653451 | 3.49E+01 | 3.60E-03 | 0.376868 |
| 8 | 2.921811 | 5.15E+01 | 2.97E-03 | 0.342254 |
| 9 | 3.293207 | 5.16E+00 | 2.34E-03 | 0.303655 |
| 10 | 3.807225 | 1.80E+02 | 1.75E-03 | 0.262659 |

Table 11. Modal analysis results of WHP Thang Long with marine growth.

| MODE | FREQ. (CPS) | GEN. MASS | EIGEN-VALUE | PE-RIOD(SECS) |
|---|---|---|---|---|
| 1 | 0.466383 | 2.74E+03 | 1.16E-01 | 2.144162 |
| 2 | 0.543426 | 3.37E+03 | 8.58E-02 | 1.840175 |
| 3 | 1.015214 | 4.07E+02 | 2.46E-02 | 0.985014 |
| 4 | 1.40029 | 2.13E+03 | 1.29E-02 | 0.714138 |
| 5 | 1.482643 | 1.62E+03 | 1.15E-02 | 0.674471 |
|  | 2.061436 | 2.18E+03 | 5.96E-03 | 0.485099 |
| 7 | 2.266151 | 2.24E+01 | 4.93E-03 | 0.441277 |
| 8 | 2.517141 | 7.63E+01 | 4.00E-03 | 0.397276 |
| 9 | 2.713164 | 2.57E+01 | 3.44E-03 | 0.368573 |
| 10 | 2.971016 | 1.94E+01 | 2.87E-03 | 0.336585 |

Table 12. Modal analysis results of WHP Thang Long without marine growth.

| MODE | FREQ. (CPS) | GEN. MASS | EIGEN-VALUE | PE-RIOD(SECS) |
|---|---|---|---|---|
| 1 | 0.501904 | 2.17E+03 | 1.01E-01 | 1.992413 |
| 2 | 0.588843 | 2.70E+03 | 7.31E-02 | 1.698246 |
| 3 | 1.048395 | 3.93E+02 | 2.30E-02 | 0.953839 |
| 4 | 1.570569 | 2.24E+03 | 1.03E-02 | 0.636712 |
| 5 | 1.654612 | 2.11E+03 | 9.25E-03 | 0.604371 |
| 6 | 2.382068 | 2.88E+03 | 4.46E-03 | 0.419803 |
| 7 | 2.928556 | 1.03E+02 | 2.95E-03 | 0.341465 |
| 8 | 3.207769 | 1.24E+01 | 2.46E-03 | 0.311743 |
| 9 | 3.392675 | 1.62E+02 | 2.20E-03 | 0.294753 |
| 10 | 3.651433 | 1.81E+03 | 1.90E-03 | 0.273865 |

Table 13. Modal analysis results od of WHP Dai Hung with marine growth.

| MODE | FREQ. (CPS) | GEN. MASS | EIGEN-VALUE | PE-RIOD(SECS) |
|---|---|---|---|---|
| 1 | 0.368827 | 7.33E+02 | 1.86E-01 | 2.711296 |
| 2 | 0.402077 | 2.29E+03 | 1.57E-01 | 2.487085 |
| 3 | 0.60992 | 7.83E+01 | 6.81E-02 | 1.639559 |
| 4 | 0.892804 | 4.27E+01 | 3.18E-02 | 1.120066 |
| 5 | 0.906706 | 3.45E+03 | 3.08E-02 | 1.102893 |
| 6 | 0.991478 | 9.49E+01 | 2.58E-02 | 1.008595 |
| 7 | 1.255309 | 1.16E+03 | 1.61E-02 | 0.796617 |
| 8 | 1.293983 | 5.57E+01 | 1.51E-02 | 0.772808 |
| 9 | 1.335043 | 6.54E+01 | 1.42E-02 | 0.749039 |
| 10 | 1.561476 | 5.02E+01 | 1.04E-02 | 0.64042 |

Table 14. Modal analysis results of WHP Dai Hung without marine growth.

| MODE | FREQ. (CPS) | GEN. MASS | EIGEN-VALUE | PE-RIOD(SECS) |
|---|---|---|---|---|
| 1 | 0.372764 | 6.92E+02 | 1.82E-01 | 2.682662 |
| 2 | 0.410744 | 2.10E+03 | 1.50E-01 | 2.434607 |
| 3 | 0.61458 | 7.62E+01 | 6.71E-02 | 1.627127 |
| 4 | 0.905531 | 3.60E+01 | 3.09E-02 | 1.104325 |
| 5 | 0.969329 | 4.26E+03 | 2.70E-02 | 1.031642 |
| 6 | 1.038733 | 1.64E+02 | 2.35E-02 | 0.962711 |
| 7 | 1.294964 | 5.79E+01 | 1.51E-02 | 0.772222 |
| 8 | 1.323036 | 1.58E+02 | 1.45E-02 | 0.755837 |
| 9 | 1.344943 | 1.20E+02 | 1.40E-02 | 0.743526 |
| 10 | 1.569746 | 3.87E+01 | 1.03E-02 | 0.637046 |

### 3.4 *Effect of Marine Growth for WHP Dai Hung*

Through Tables 2,3 and 4 above, we find that the estimated thickness of the marine growth is approximately the same as the actual thickness of marine growth and does not vary too much. However, according to Tables 1 and 4, the estimated thickness of marine growth is smaller than the actual thickness surveyed in 2013. Therefore, we analyzed the WHP Dai Hung with the actual marine growth data above, with the following results.

Table 15. Modal analysis results of WHP Dai Hung with actual marine growth.

| MODE | FREQ. (CPS) | GEN. MASS | EIGEN-VALUE | PE-RIOD(SECS) |
|---|---|---|---|---|
| 1 | 0.363 | 7.95E+02 | 1.92E-01 | 2.754819 |
| 2 | 0.392034 | 2.52E+03 | 1.65E-01 | 2.550802 |
| 3 | 0.604355 | 8.07E+01 | 6.94E-02 | 1.654657 |
| 4 | 0.867647 | 3.70E+03 | 3.36E-02 | 1.152542 |
| 5 | 0.877786 | 5.51E+01 | 3.29E-02 | 1.139231 |
| 6 | 0.965693 | 6.36E+01 | 2.72E-02 | 1.035526 |
| 7 | 1.203706 | 1.06E+03 | 1.75E-02 | 0.830767 |
| 8 | 1.292462 | 5.48E+01 | 1.52E-02 | 0.773717 |
| 9 | 1.333672 | 6.39E+01 | 1.42E-02 | 0.74981 |
| 10 | 1.519112 | 2.14E+02 | 1.10E-02 | 0.658279 |

Table 16. Effect of marine growth on the DAF values.

| Model | With marine growth | Without marine growth | % Difference |
|---|---|---|---|
| WHP Thai Binh | 1.041 | 1.039 | **0.192** |
| WHP Thang Long | 1.077 | 1.066 | **1.031** |
| WHP Dai Hung | 1.046 | 1.045 | **0.095** |

Table 17. Effect of marine growth on the wave loading.

| | With marine growth | | | Without marine growth | | | |
|---|---|---|---|---|---|---|---|
| Model | Fx (kN) | Fy (kN) | $F_w$ (kN) | Fx (kN) | Fy (kN) | $F_{wo}$ (kN) | % difference |
| WHP Thai Binh | 90.27 | 70.70 | 114.66 | 86.70 | 59.08 | 104.92 | **9.28** |
| WHP Thang Long | 75.80 | 94.25 | 120.95 | 67.76 | 84.21 | 108.08 | **11.90** |
| WHP Dai Hung | 288.11 | 24.52 | 289.15 | 271.2 | 21.88 | 272.15 | **6.247** |

Table 18. Effect of marine growth for WHP Dai Hung.

| Parameters | Estimated marine growth by metocean criteria | Actual marine growth by survey report 2013 |
|---|---|---|
| $T_1$ (s) | 2.71 | 2.75 |
| DAF | 1.046 | 1.048 |
| % difference of DAF | **0.191** | |
| $F_x$ (kN) | 288.11 | 308.33 |
| $F_y$ (kN) | 24.52 | 26.50 |
| $F_w$ (kN) | 289.15 | 309.47 |
| % difference of $F_w$ | **7.027** | |

## 4 CONCLUSIONS

The effect of the marine growth on jacket structures was investigated on three different real models. Use to static in-place analysis to determine the Dynamic Amplification Factor (DAF). The effect of marine growth was investigated on both the wave loading and the DAF values. From the results of the presented study in this paper, the following conclusions can be drawn:

1. The estimated thickness of marine growth at the design step differs from the actual thickness of the surveyed marine growth. In some jackets, the estimated thickness of marine growth is expected to be smaller than the actual thickness.
2. The existence of marine growth that can be accumulated with time has a significant effect on increasing wave loading, differences from 6.24% to 11.90%.
3. For jackets was found that the marine growth has insignificant effect on the DAF values, the biggest difference is 1.03%.
4. From this analysis of WHP Dai Hung, it is found to be essential to prevent and remove marine organisms from the jacket structure to allow for inspection as well as to relieve the wave loading.

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