

Base Shear and Overturning Moment on Jacket Structure with Marine Growth

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Abstract - The present of marine growth attached on any submerged section of offshore installation will significantly affects the loading magnitude and its related response. Basic consideration must be given at earlier stage of design process of this structure so that the appropriate design allowance be introduced in the structure's final dimensions. This paper investigates the effects of marine growth presence on structural response in particular the base shear and it associated overturning moment. Base shear was increased by more than 130 percent as compared to newly installed structure. Overturning moment was increased by about 110 percent due to increases in marine growth on the submerged section of the structure.

Keywords -- jacket structure, marine growth, structural response, shear force, overturning moment.

I. INTRODUCTION

This paper investigates the basic response of jacket structure to environmental loading. Particular attention was given on the response of base shear and overturning moment in the presence on marine growth attached to the outer surface of the jacket's submerged members. The environmental parameters considered in this study comprises of wave height, wave period, current velocity, force coefficients, wind parameters and the distribution of marine growth. The studies performed and the criteria used for each study are given in the following section. The range of values chosen for each parameter is applicable for the Southern North Sea sector and they are either used in current design practice or in present research predictions. The assessment of structural response was performed for wave action coming from one direction of attack only because the configuration of the structure has a square plan shape and a wave phase angle of 35 degree gave a distinct maximum loading on to the structure [1].

II. STRUCTURAL MODEL AND GEOMETRY

A four-legged jacket structure is modeled and analyzed in this study. The structure is assembled from a tubular steel of certain diameter and thickness according to specified designed dimensions. The

structural parameters are determined with consideration of loadings and response that are likely to experience by the structure in its service life. The prediction of loading at its possible extreme values as well as consideration of safety expects of the structure fixed in its location throughout the intended design life.

Fig. 1 shows a jacket structural model considered in this study that was installed at water depth of 25.06 m in the Southern North Sea. The structure is a four-legged platform having horizontal, vertical and inclined members then piled-fixed to the seabed. The square cross-section jacket measures 17.3 m x 17.3 m (plan view) at the base and 9.84 m x 9.84 m at elevation (+)5.65 m. It has the same measurement (9.84 m x 9.84 m) down to elevation (+)15.82 m. The jacket consists of four large-diameter tubular legs framed together by a large number of smaller tubular braces. These legs have diameter of 0.838 m and thickness of 0.0127 m extended from elevation (-)25.06 m to elevation (+)15.82 m above MSL. They extend with a batter 1 in 5.822 from sea bed to elevation (+)5.65 m then vertically from elevation (+)5.65 m to elevation (+)15.82 m. Jacket legs are battered to provide a larger base for the jacket at the mud-line and thus assist in resisting the environmentally induced overturning moments.

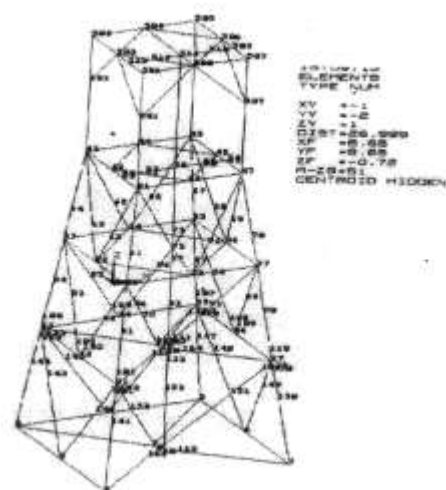


Fig.1. Jacket structural model.

III. LOADING FORMULATION

Loadings on the structure are coming from the environment predominantly contributed by waves. Other environmental loading input are from wind and current. Base case loading parameters considered in this study is presented in Table 1.

TABLE 1. Base case Parameters

Parameter	Value
Wave Theory	Small amplitude wave theory
Current Profile	Stretch
Wave-current interaction	Stretch
Maximum wave height, Hmax (m)	16.8 m
Maximum wave period, Tmax (sec)	13.1 sec
Phase angle (degree)	35
Water depth, d (HAT)	27.54 m
Drag coefficient, Cd	0.6
Inertia coefficient, Cm	2.0
Current velocity: (surface/seabed) m/s	1.55/0.97
Marine growth thickness	None

Loading and response due to these input parameters are considered as a base case response in comparison with others load cases that follows.

The Airy wave theory is assumed in this study where the wave amplitude a , is considered very small as compared to the water depth, h . Wave loads on submerged section of jacket structure estimated using Morison equation [2].

$$F_{wave}(z, t) = \frac{1}{2} \rho C_D A u |u| + \frac{\pi}{4} \rho C_M D^2 \dot{u}$$

Water particles velocities in x-direction, u and z-direction, v at any point of time, t is given as:

$$u(x, t) = \frac{\pi H \cosh[k(z+h)]}{T \sinh(kh)} \cos(kx - \omega t)$$

$$v(x, t) = \frac{\pi H \sinh[k(z+h)]}{T \sinh(kh)} \sinh(kx - \omega t)$$

The associated acceleration of water particles, \dot{u} and, \dot{v} at any point of time, t is defined as:

$$\dot{u}(x, t) = \frac{2\pi^2 H \cosh[k(z+h)]}{T^2 \sinh(kh)} \sinh(kx - \omega t)$$

$$\dot{v}(x, t) = \frac{-2\pi^2 H \sinh[k(z+h)]}{T^2 \sinh(kh)} \cos(kx - \omega t)$$

Sea driven current velocity that accompanied the wave particle motion is estimated using the following relationship;

$$v_{ct} = v_{cto} \left(\frac{z+d}{d} \right)^{\frac{1}{7}}$$

where v_{cto} is current velocity at mean sea level, z is distance from the surface and d is water depth.

Wind force exerted on the structure at elevation Z , can be calculated as below relationship:

$$F_w = \frac{\rho}{2g} (\bar{U})^2 C_s A$$

where ρ is density of air, g is gravity acceleration, \bar{U} is wind speed, C_s is shape factor A is projected area of the structure.

Initially, the analysis is performed for the structure that is newly installed, assumed to be a clean structure, i.e. free from any attachment of marine growth. Force coefficients assumed for this model are $C_d = 0.6$ and $C_m = 2.0$ [3]. The effects of marine growth on the response of the structure are investigated by using appropriate values of drag coefficients for particular type and thickness of marine growth attached onto the structural members. The value of C_d as suggested by the API code is $C_d = 1.05$, [4], [5]. Structural response values of base shear (BS) and overturning moment (OTM) are found to be 3.01 MN and 59.55 MNm respectively.

In this study, wave height of 16.8 m and water depth of 27.54m were selected together with four sets of marine growth thickness to investigate the sensitivity of structural response due to the presence of marine growth as shown in Tables 1 and 2. The wave height of 16.8 m is referred to 100-year return period for Southern North Sea area. Data on the distribution of marine growth distribution are typical of the North Sea platform. Data first collected are labelled as baseline thickness 'B' and follows with data two years (B+2), five years (B+5) and ten years (B+10) after the baseline survey [6].

TABLE 2. Marine growth study

Parameter	Value
Wave height (m)	16.8
Wave period (s)	13.1
Water depth (m)	27.54
Drag coefficient, Cd	Vary (depending on surface roughness)
Current velocity; Surface/seabed (m/s)	1.55/0.97
Marine growth thickness	Case 1: None Case 2: Baseline thickness (B) Case 3: B+2 years Case 4: B+5 years Case 5: B+10 years

The thickness of marine growth associated with its distribution are considered in the modeling of overall structural sizes and design parameter values. The distribution are divided into zones that ranges the availability of marine growth species attached to the structure observed during the survey.

Example of the distribution of marine growth thickness on the structure are shown in Fig. 2. The baseline thickness of marine growth (B) is the initial

thickness of marine growth first measured on the structure. Surface roughness due to marine growth is determined from related values of Cd is obtained from Jusoh and Wolfram [7]. In all cases the values of Cm is assumed to be 2.0.

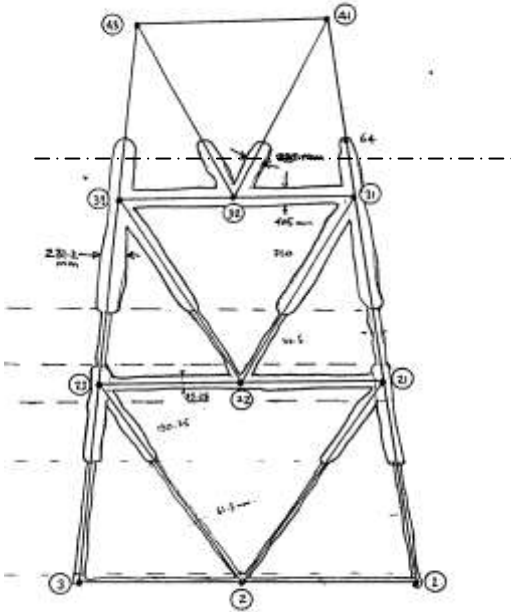


Fig. 2. Distribution of marine growth, Baseline thickness (B),

Generally, the duration of structure’s submerged after installation in a location will has a bearing on the increment of marine growth thickness attach to its surface. This condition will directly correspond to the loading on the structure.

IV. RESULTS AND DISCUSSION

The results of this study are given in Tables 3 and 4. Results shows variation of base shear and overturning moment for structures with baseline, baseline + 2 years, baseline + 5 years and baseline + 10-years marine growth thickness attached to it submerged surface. Table 4 shows the effect of increase in marine growth thickness as percentage increases in base shear and overturning moment relative to both the clean structure and the structure with baseline thickness.

TABLE 3. Effects of marine growth on structural loadins.

Marine growth thickness	None	Baseline	B+2 yr	B+5 yr	B+10 yr
Base shear (MN)	3.07	5.65	7.11	6.56	7.15
OTM (MNm)	59.50	97.21	124.87	112.16	122.80

The results are plotted for base shear and overturning moment versus time as shown in Fig.3 to Fig. 5. It should be noted that the baseline survey was some years after initial installation of the structure.

TABLE 4. Percentage increase in BS and OTM due to marine growth

Marine growth thickness	None	Baseline	B+2 yr	B+5 yr	B+10 yr
Base shear (MN)	3.07	5.65	7.11	6.56	7.15
% increase to clean structure	-	84.04	131.60	113.68	132.90
% increase to baseline thickness	-	-	25.84	16.11	26.55
OTM (MNm)	59.50	97.21	124.87	112.16	122.80
% increase to clean structure	-	63.38	109.87	88.50	106.39
% increase to baseline thickness	-	-	28.45	15.38	26.32

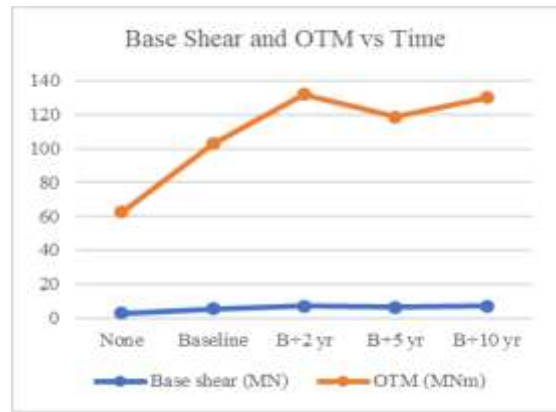


Fig. 3. Increase in Base Shear and OTM with time after jacket installation.

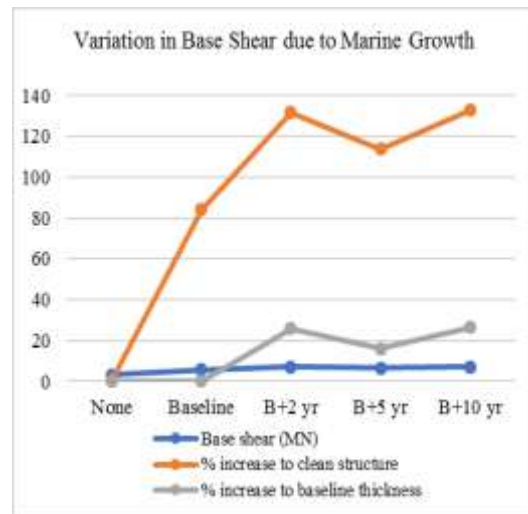


Fig. 4. Variation of Base Shear and percentage increment in marine growth thickness with time after jacket installation.

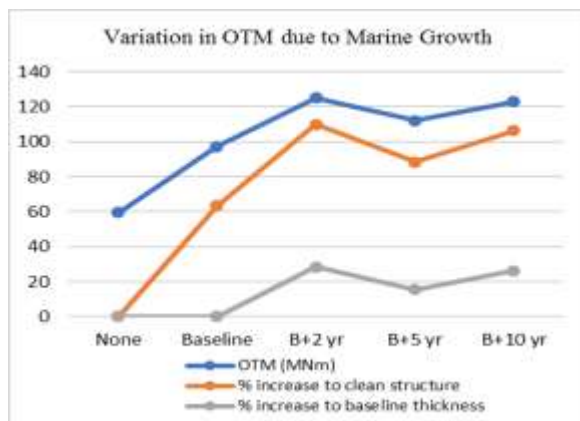


Fig. 5. Variation of OTM and percentage increment in marine growth thickness with time after jacket installation.

These figures show that variation of base shear and overturning moment due to the effects of marine growth are significantly increased with time in service. This of course is not in any way good in the long term from the maintenance of the structure point of view. From design aspects due allowance has to be given for these increments in submerged member's diameter and its associated responses. Another side of the activity for the safety practice of the structure, one operator has to determine when is the right time for cleaning to take place hence reducing the effect on the overall loading of the structure.

The study also shows an expectedly high magnitude in total structural loading attribute to the presence of marine growth over some period of time. These results are given in Tables 3 and 4. The baseline thickness of marine growth on the structure gives extra loading of about 84% compared to when the structure was first installed (i.e. clean) and extra load increased up to around 130% of the clean structure after gaining fouling growth of baseline thickness plus 2 years (B+2).

However, the increment of shear loading due to marine growth thickness above baseline thickness are found to be in the order of less than 30%. The increment in overturning moment due to marine growth above the baseline thickness is of similar magnitude. Percentage increases in overturning moment as compared to the clean structure is about 110% and about 30% respectively compared to a structure with marine growth of baseline thickness. The results show a marked reduction in marine growth thickness and its associated loading during survey activity at (B+5) years. This is due to the condition where some of the marine growth grows thicker and dislodged from the structure due to heavy environmental interaction on to the structure.

From these figures it is very important to acknowledge the significance of the presence of marine growth on the structure and its related acceptable loading allowances at the design stage.

The result shown are applicable to the structure with the same thickness of marine growth

distribution. The consideration of average thickness of marine growth for other sector of the North can be referred in Wolfram *et al*, [6]. These results are in good agreement with other studies [6], [9], [10]. In this study, magnitude of OTM is referred to one angle incident with wave as referred to [1], however other study shows effects of multi-directional angle of wave incident as reported in [11].

V. CONCLUDING REMARKS

The results of the study were used to examine the effect on general loading in terms of percentage change in base shear and overturning moment for associated changes in marine growth thickness parameter. The result shows that base shear and overturning moment are significantly increased with respect to structure's submerged duration respectively. Maximum values from this study; Base shear increases in the order of 132.90 percent and 26.55 percent compared to clean structure and baseline line values respectively. Overturning moment increases by 109.87 percent and 28.45 percent compared to clean structure and baseline line values respectively.

The trends obtained from this study are representative of a typical shallow water structure for the Southern North Sea and are indeed applicable for a similar type of structure. Application to structures outside this area must be assumed with caution.

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