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RESEARCH ARTICLE

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ANALYSIS AND DESIGN OF PRE-ASSEMBLED PIPERACK DURING SEA TRANSPORTATION CONDITION

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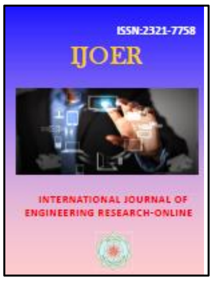


ABSTRACT

Pipe racks are framed structures that support pipes and auxiliary equipment in the process areas of industrial plants**.** Pre-Assembled Pipe-rack is used to overcome the issues like remoteness of site, labor shortage, and tight project schedule. Pre-assembled modules (PAM) building process employs the fabrication of permanent structural steel framework with temporary foundations, and it is used for the purpose of maximizing the transfer of man hours off site and reducing overall construction time. This paper provides the description of the structural analysis of the framework under sea transportation to obtain the stresses and deflection of the structure. Module will be transported to the in-place site location. The global design analysis and design of an offshore module of 4m*20m*4.6m length, width and height respectively is considered to check the sea transportation analysis feasibility of the module in all load cases and design aspects. The structural analysis is performed considering in-place as the first stage of process, sea transportation was the second stage, considering corresponding transportation loads

Keywords— acceleration, motion, Piperack, prefabrication, utility check

1. Introduction

Pre-assembled pipe-rack are widely used for industries and oil & gas sectors compared with traditional stick-built construction. Pre-assembled modules can accelerate the construction schedule for maximization of shop fabrication, resulting in lower field installation cost. Modular steel structures are the common method of construction in the arctic region where they are largely used by the oil and gas industry to support and enclose process equipment's. in major modular construction projects, predominant in construction sites which experience severe weather conditions, heavy modules structures are usually pre-assembled in the fabrication yards are transported on sea ways using barges of standard and available sizes, road ways using multi wheel transporters commonly known as self-propelled modular transportation or rubber tire vehicle and finally lifting using crane system either to project site or designate lay down areas using build up static and dynamic forces in the structures. The behaviour of the structure is unpredictable and difficult to analysis during sea transportation condition. Module behaviour of pipe rack has to be conceptualized using simplistic approach and stimulated in staad offshore software to analyse the module. The purpose of the module analysis is to obtain the stresses in the module due to motion generated acceleration during sea transportation condition for primary members and join design

2. Sea Transportation Loading Condition

During in-place conditions dead loads are influenced over the Piperack structures are pipe loads, E&I cable loads, grating loads and paint loads. when the structure is carries over the deck, it undergoes wind loading condition and due to tilting effect causes the deflection over the structures

3. Dead loads

The structural weight comprises primary, secondary and outfitting steel. The secondary load consists of grating, pipe supports and cable tray supports secondary and outfitting steel will be a percentage of the primary steel weight, unless a specific weight is defined

Pipe empty weight = 2 kN/m2

Cable tray empty weight = 1 kN/m2

Secondary dead load

Grating load = 1kN/m2

Pipe supports and cable tray supports = 10% of empty weight

Painting load = 5 % of structural dead weight

Dead load cases	Intermediate members (kN/m)	End members(kN/m)
Pipe empty weight	5	2.5
Secondary empty weight	3.1	1.6

profile	Length (m)	Weight (kN)
ST IPE300	152	62.974
ST HE300A	18.4	16.011
ST HE200A	43.4	17.981
LD L90*90*7	63.72	12.051
LD L75*75*7	102.45	16.016
	TOTAL	**125.033**

Total length = 380 m

5% of total weight = 6.25 kN

Load on member = 6.25/380 = 0.016 kN

4. Wind load calculation

Wind loads are calculated by using API-RP2A code based on 1h

(1). $F = \rho/2 \times C_s \times A \times U^2_{(z\,t)}$

(2). $U_{(zt)} = U_{(z)} \times [1-0.41 \times Iu_{(z)} \times \ln(t/t_o)]$

(3). $Iu(z) = 0.06 \times [1 + 0.0131 \times U_o] \times (z/10)^{-0.22}$

(4). $U_z = U_o \times [1+C \times \ln(z/10)]$

(5). $C = 0.0573 \times \sqrt{(1 + 0.0457 \times Uo)}$

Here ρ = mass density of air (1.226Kg.m³), C_s = shield coefficient, A = wind surface (meter square), $U_{(zt)}$ = 1 min mean wind speed expressed in m/s at the considered elevation, t_o = 3600 s, U_o = 26.9 m/s from table 4.4 API-RP2A , 1 hr wind speed @ elevation 10m = 26.9 m/s, Air density= 1.226 kg/m3, Gust duration = 60 s, Sea water level= 100m, datum level= 107.5m

items	Width	Height	A	Load @ nodes
	m	m	M2	kN/m
Bow to stern	20	4.6	92	13.68
Starboard to bow	4	4.6	18.4	2.73
Stern to bow	20	4.6	92	13.68
Port to starboard	4	4.6	18.4	2.73

5. Inertia forces due to motion

The inertia force are generated by vessel motions and comprises three translational forces due to surge, sway and Heave plus three rotational forces due to Roll, Pitch and Yaw. The inertia loads for analysis will be generated within Staad.Offshore

For the load motion Staad.offshore is used to generate Roll and Pitch motions only, Heave and Gravity effects are generated by Notional loads Due to inclination, a mass located in space, the mass will be resolved into components parallel and perpendicular to vessel according to the inclination angle Γ is set as the inclination of the barge around Z axis and α is set as the inclination of the barge around the X axis. For the angle effect on the barge the weight components parallel and perpendicular to the barge are

(1). F_{hx}= W x Sin γ= mg (1+a_{heave}) x Sin γ

(2). F_{hz}= W x Sin α= mg (1+a_{heave}) x Sin α

(3). F_V=WxCosγCosα= mg (1+a_{heave}) x CosγCosα

In order to isolate only the dynamic acceleration, the vertical effect is subtracted from the equation

Dynamic linear acceleration:

(1). $ah_x= (-1 \pm a_{heave})$ xSin γx g

(2). $ah_Z= (1 \pm a_{heave})$ xSin αx g

(3). $a_V=((-1\pm a_{heave})$ (CosγCosα) +1)x g

where a_{heave} =0.2g (heave factor)

6. *Load combination*

(1). ± Roll ± Heave

(2). ± Pitch ± Heave

(3). ± 80% Roll ± 60% Pitch ± 100% Heave

(4). ± 60% Roll ± 80% Pitch ± 100% Heave

(5). ± Roll ± Heave ± Wind (Z) + Vessel Sagging

(6). ± Pitch ± Heave ± Wind (X) + Vessel Sagging

(7). ± 80% Roll ± 60% Pitch ± 100% Heave ± 80% Wind (Z) ± 60% Wind (X) + Vessel Sagging

(8). ± 60% Roll ± 80% Pitch ± 100% Heave ± 60% Wind (Z) ± 80% Wind (X) + Vessel Sagging

(9). ± 80% Roll ± 60% Pitch ± 100% Heave ± 80% Wind (Z) ± 60% Wind (X) + Vessel Hogging

(10). ± 60% Roll ± 80% Pitch ± 100% Heave ± 60% Wind (Z) ± 80% Wind (X) + Vessel Hogging

7. Piperack module Design and Analysis

The pipe rack is consisting of framed structures, its used for supporting pipelines and auxiliary equipment in the process areas of industrial plants, Basically the pipe-rack are welded tubular space structures consisting of structural components as vertical and horizontal members, vertical and choroidal braces. Each component in the pipe-rack has its own purpose which provides the structural integrity for the platform

8. Vertical and Horizontal members

These are the primary members of the Piperack structure which are used to take care of the major permanent loads coming from the structure

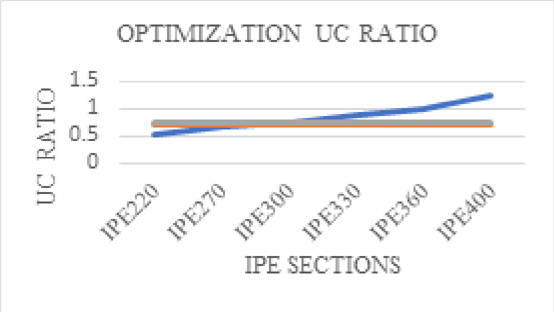
9. Vertical and Horizontal braces

These are the secondary members which is used to carry the lateral forces acting over the Piperack and mainly used for taking care of shear forces acting over the Structure

Here the Piperack is designed as the rectangular structure having the cross section of 4m*20m*4.6m width, length and height respectively. The design analysis are performed for a module considering of two level of deck. The dead loads include weight of structure, equipment, pipe and other items which form a permanent part of installation. Here, the characteristics value of a dead load is taken as the expected average based on material density and volume. The weight contingency of 1.10 is applied to self-weight in order to take connection details weight as part of the permanent weight. all the permanent dead load cases are applied to the structure. center of gravity is obtained from the total static load case of staad pro module. The module should always be positioned on the deck with one centerline coincide with the longitudinal centerline of the vessel. For inertia load analysis, horizontal restraints will be applied to replicate the actual pitch and roll restraints. Wind load are applied as per API-RP2A formula based on 1hr mean speed as per mentioned above the table. Barge acceleration are action loads which will be applied on the module in transportation condition. These acceleration loads will be calculated and applied according to Nobel Denton (section 7.9 table 7-2 default motion criteria) guidelines for marine transportation. In order to obtain the inertia forces COR data is given for rotational force generation, mass of the total static load case is added and pitch factors are added as per Noble Denton standards. Roll and pitch effects are generated via these inputs

10. Design Optimization

Optimization of Piperack are done to decrease the cost to weight ratio. In general optimization research work carried by many researcher and their study provides ideas on various perspective with respect to which optimization can be done. To do optimization researcher adopt different methodology and technique having the cause of optimization as objective function which varies from structure to structure. Initially before starting the optimization of the Piperack certain boundary conditions are set like Unity check and deflection check. These conditions are assigned by trial and error method and fixed in-between 0.7 to 0.75 as they are found optimum for design. The graph is plotted between maximum UC ratio of the vertical members of Piperack to different IPE sections from the European data base. The section identified from the section comes under the optimum UC ratio value given by the client. As the same time the displacement to be checked for the section



Conclusion

The structural design and optimization of pre-assembled Piperack has obtained a proper weight structure that has sufficient capacity and strength with respect to sea transportation condition. The modelling and design analysis and optimization are performed based on elastic behavior of structural members. The linear elastic analysis is applied to find the structural members that have less and high utility check ratio. The global analysis of the Piperack module shows that the structure at operational phase has sufficient capacity to withstand the load at sea transportation phase and utility ratio indicates the structure has sufficient reserve capacity, offshore structures are frequently evaluating of operational life, and/or modification to enable further facilities and developments. Thus, the reserve capacity of the structure can be used in future modification of the structure safely. The results imply that the structure has sufficient capacity to withstand all construction phases with respect to design criteria and also it can safely transport by a deck.

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