Environmental Effects on Ship Structures at Sea using Finite Element Method

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ABSTRACT
Ship is the largest man made vehicle on the earth. Ship is emerging through two different fluids air and seawater which is different scenario than other moving vehicle. So naval architect need to consider the effects due to air and sea water while designing the ship. Every ship continually disturbed by the waves, wind and currents resulting horizontal and vertical motion loads on the ship. Because of bad environmental conditions such as heavy wind and storms, ship experiences linear and rotation motions at sea. These motions crates significant effect on certain marine operations such as drilling, pipe laying, fishing etc. The main purpose of this paper is to study the ship motion effects on structures of the ship. Equipment on main deck is considered for the present study, there are several types of equipment to be placed on the main deck of the ship for mooring, towing, lifting and so on. These equipment are named as deck equipment or deck fittings. In this paper behavior of supporting structure of a lifting crane is considered.

Keywords—Ship; mooring; towing; drilling

I. INTRODUCTION
Ship motions are always challengeable to the Naval Architects, when the ship is on voyage condition it is subjected to bad environmental conditions. Ship is the biggest man made moving vehicle. Ship is playing vital role to transport goods from one port to another port through ocean. Ship floats on the sea water based on Archimedes principle. Total weight of the ship is balanced by the fluid force which is called buoyancy force. The bad environmental conditions in the sense waves, winds, storms, all these environmental effects needs to be consider while designing the ship then only ship withstands over these effects. Prediction of ship motions and dynamic sea loads is a complex problem. Naval architect should consider the wave induced bending moment on the hull girder. Hull girder strength includes the decks, side shell, main stiffeners and internal stiffeners. Even though wave induced bending moment effect is considered on the hull girder, ship motion effect causes local failure. This paper describes the local strength difference between static condition and dynamic condition. Det Norske Veritas (DNV) code is followed to calculate the ship motions and accelerations. Structural strength of ship structures can be assess by using various 3-D software, out of those ANSYS is user friendly and accurate. ANSYS 12.0 is used for present study.

Ship at sea is a six degree of freedom object at sea, which means free to move in any direction. Ship has three translation motions and three rotational motions at sea.

Three translations are:
- Surge – Along the length of the ship
- Sway – Along the breadth of ship
- Heave – Along the depth of the ship

Three rotations are:
- Roll – About longitudinal axis of the ship
- Pitch – About transverse axis of the ship
- Yaw – About vertical axis of the ship

When ship is at sea structural behavior is varies from static condition. Behavior of ship at sea mainly depend on wave height and wave attacking angle. Wave height is double the amplitude of wave profile. Wave height can explained by using WMO (World Metrological Origination) Sea state code. Sea state is the general condition of the free surface on a large body of water with respect to wind, waves at a certain location and moment. A sea state is characterized by statistics, including the wave
height, period, and power spectrum. The sea state varies with time, as the wind conditions change. Based on sea state code sea can be classified as calm, moderate and storm conditions.

Table 1 shows the sea state classification

<table>
<thead>
<tr>
<th>Sea state</th>
<th>Wave height (meters)</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Calm (glassy)</td>
</tr>
<tr>
<td>1</td>
<td>0 to 0.1</td>
<td>Calm (rippled)</td>
</tr>
<tr>
<td>2</td>
<td>0.1 to 0.5</td>
<td>Smooth</td>
</tr>
<tr>
<td>3</td>
<td>0.5 to 1.25</td>
<td>Slight</td>
</tr>
<tr>
<td>4</td>
<td>1.25 to 2.5</td>
<td>Moderate</td>
</tr>
<tr>
<td>5</td>
<td>2.5 to 4</td>
<td>Rough</td>
</tr>
<tr>
<td>6</td>
<td>4 to 6</td>
<td>Very rough</td>
</tr>
<tr>
<td>7</td>
<td>6 to 9</td>
<td>High</td>
</tr>
<tr>
<td>8</td>
<td>9 to 14</td>
<td>Very high</td>
</tr>
<tr>
<td>9</td>
<td>Over 14</td>
<td>Phenomenal</td>
</tr>
</tbody>
</table>

Wave attacking angle also important parameter to consider when the ship is at sea. Wave attacking angle is the angle between ship transiting direction to and wave direction. We can’t decide the wave direction towards ship, depends on the wave direction towards ship, sea can differentiated as Head sea, Oblique Sea, Beam Sea and following sea.

II. PROCEDURE

DNV-Rules for classification of ships. Hull structural design, Ships with length more than 100 m and above explains the procedure to calculate the ship motions and accelerations. Consider a ship of general cargo carrier for the present study. Consider this ship is built as per Det Norkes Veritas (DNV) class code. For general cargo ships there are cranes near to cargo holds on the main deck of the ship to load and unload the cargo at port. The crane legs land on the main deck, so the landing deck area should be stronger than the remaining deck structure. The legs landing deck area should be designed for full capacity of the crane. When the vessel is subjected to motions horizontal loads comes in to act (longitudinal and transverse direction) these effects also need to be consider while designing the crane supporting structure.

Two case are considered for the present study, first one is vessel at still water condition, second case is ship is on voyage condition and subjected to wave effects. In the first case only crane self-weight is considered there is no horizontal force since it is at static condition. In the second case in addition to self-weight of the crane motion effects also considered. The horizontal effects and excessive vertical effects are calculated as per DNV code.

Considered ship particular considered for the present study are,

- Length = 188.9 m
- Breadth = 32.3 m
- Depth = 18.0 m
- Draught = 12.5 m
- Block coefficient = 0.82
- Design speed = 12 knots

Crane center of gravity position, 64.5 m from the mid ship, 14.0 m from the center line, 2.0 m above the main deck

Rules for ships part-3 chapter-1 Section-4-B describes the procedure for calculating the ship motions and accelerations for ships length more than 100 meters. By using this procedure ship accelerations are calculated and added as Appendix.

III. MODELING AND BOUNDARY CONDITIONS

Model consider for the present study is at main deck level of general cargo ship. Crane weight is applied as space load on the deck where the crane legs are landing, so model includes the cargo lifting crane supporting structures, model is somewhat extended away from crane legs landing area. Model is built by using 4 node shell element in Ansys. Model includes the only 2-D, so in-plane boundary conditions are applied. Self-weight of modelled structure and crane weights are the static loads for present analysis.

In general crane on cargo ship located at center line of vessel, for the present study crane location is considered 14.0 m away from center line because of this assumption accelerations are more comparatively crane at center line.
IV. RESULTS AND DISCUSSION

Considered two cases are mentioned below,

i. Static condition: Only static loads are considered
ii. Dynamic condition: Accelerations due to ship motions are considered with static loads.

Case1: Static condition

In the static condition self-weight of modeled structures and crane self-weight is applied at its center of gravity. With this loading condition equivalent stresses are observed as shown in the figure 4.

Case2: Dynamic condition

In the dynamic condition self-weight of modeled structures and crane weight is applied with ship motion acceleration effects. With this loading condition equivalent stress are observed as shown in the figure 5.

V. CONCLUSION

From the result plots shown in figure 4 & 5, in the first case (static condition) the equivalent stress is 64.82 N/mm² from the figure 4. In the second case (Dynamic condition) equivalent stress is 101.31 N/mm² from figure 5, which is comparatively higher than the first case. From these two results it is observed equivalent stress in dynamic condition is 56.3% higher than the static condition, which creates structural damage if a designer not considered dynamic effects. So while designation the foundation to deck equipment or any foundation on ship decks it is important to consider ship motions and acceleration effects.

Appendix-Acceleration calculations
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