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Araştırma Makalesi

İki Gemi Baş Tasarımı İçin Dalga Eğilme Moment Analizi Üzerine Bir Çalışma

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ÖZET

Bir geminin yapısı, servis ömrü boyunca geminin deneyimleyeceği statik ve dinamik yüklere dayanacak şekilde tasarlanmıştır. Dalgaların hareketi ve ortaya çıkan gemi hareketlerinin etkileri ile geminin tekne yapısına dinamik yükler uygulanır. Bu çalışmanın amacı, iki farklı gemi baş tasarımı ile teknenin düşey dalga eğilme momentinin değerlerini analiz etmektir. Hidrodinamik yükler WASIM bilgisayar programı kullanarak hesaplanıyor ve bu kapsamda geminin NAPA dataları, tekne ofset tablosu ve yükleme koşulları dikkate alınıyor. Yükleme koşulu özet tablolarından, analiz için bir tam yük koşulu seçilir. WASIM hesaplamaları, seaworthy başlı ve balb başlı ile dalga dikey bükülme momentinin ortasında gerçekleştirilmiştir. Dikkate alınan yükleme koşulu, homojen bir tam yük koşuludur. MLER dalgalarındaki teknenin doğrusal olmayan WASIM hesaplamaları, tam yük koşulu için, seaworthy başlı teknenin en yüksek dalga dikey eğilme momenti gemilerinin, balb başlı teknenin muadil değerinden % 2.6 daha yüksek olduğunu göstermektedir.

Anahtar Kelimeler: Dalga eğilme momenti, hidrodinamik analiz, gemi hareketleri, tekne yapısı

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Research Article

A Study on Wave Bending Moment Analysis for Two Bow Designs

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ABSTRACT

A ship's structure is designed to withstand the static and dynamic loads to be experienced by the ship throughout its service life. Dynamics loads are exerted on the ship's hull structure through the action of the waves and the effects of the resultant ship motions. The objective of the study is to analyse the vertical wave bending moment amidships of the vessel with the two different bow designs. The hydrodynamic loads are calculated with the computer program WASIM based on loading condition summary tables, ship hull offset tables and NAPA database of the vessel. From the loading condition summary tables, one full load condition is selected for the analysis. WASIM calculations have been carried out of the wave vertical bending moment amidships with a bulbous bow and a seaworthy bow. The considered loading condition is a homogenous full load condition. The nonlinear WASIM calculations of the vessel in the MLER (Most Likely Extreme Response) waves show that for full load condition, the highest wave vertical bending moment amidships of the vessel with the seaworthy bow is 2.6% higher than the counterpart value of the vessel with the bulbous bow.

Keywords: Wave bending moment, hydrodynamic analysis, ship motions, hull structure

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1. Introduction

Ship hull girder loads consist of dynamic and static parts. The most significant of those parts are the still water bending moments and shear forces. The still water part results from the difference between the distributions of the various weight items and the distribution of the supporting buoyancy forces along the vessel length. The weight items include lightweight of the vessel, cargo weight and weight of consumables. The dynamic loads include wave induced hydrodynamic loads, sloshing, slamming, inertia loads due to ship motion and impact loads. The dynamic wave induced loads include the vertical and horizontal shear forces, bending moments and torsional moments. Wave loads are assessed by means of one of the two methods such as design wave method and spectral analysis method. The latter method is based on either short or long-term predictions, transfer functions, and the assumption that loads are linearly dependent on wave height. Depending on the loading condition of the ship, the still water bending moments and shear forces are calculated by means of the classification societies rules. A more detailed analysis is needed when determining the dynamic components of the hull girder loads for extreme sea conditions that the ship is bound to encounter over its lifetime (Shama, 2013).

Clauss and Klein (2016) investigated the effect of the bow geometry on the vertical bending moment on the basis of three types of ships and the influence of two different freeboard heights on the vertical bending moment for one ship. It was shown that large bow flares and freeboard heights contribute significantly to the vertical bending moment. Further, the critical loads and motions depend most notably on combinations of wave height, wave group sequences, crest steepness, encountering velocity and the ships target position.

Temarel et al. (2016) evaluated the methods used for the assessment of wave-induced loads on ships examining analytical, numerical and experimental approaches. The study focused on conventional ocean going vessels and loads originating from steady state and transient excitations, namely slamming, sloshing and green water, for the latter, and including extreme or rogue waves, as well as the more occasional loads following damage.

Rajendran et al. (2016) analysed the vertical responses of a bulk carrier, containership and a passenger ship using linear to fully body nonlinear numerical methods based on strip theory. The ships were classified based on their bow flare angles and the effects of the bow flare variation on the vertical responses were investigated numerically. The numerical ship responses in abnormal waves and extreme sea conditions were compared with the measurements. The extreme loads acting upon the ships were also compared with the rule vertical bending moment.

Parunov et al. (2004) addressed the calculation of design vertical wave bending moments for unconventional oil tankers of new generation that were defined by low length-to-beam ratio. The linear strip theory was used for the calculation of transfer functions, while standard IACS procedure was employed for long-term prediction of extreme values. Some recommendations with regards to incorporation of hydrodynamic analysis for the calculation of extreme wave loads in ship design were provided.

Fonseca et al. (2010) investigated the vertical motions and bending moments of a FPSO vessel in regular waves and in several design storms with a duration of three hours corresponding to the 100 years return period of the Norwegian ocean. The aim was to determine the relevance of abnormal waves with regard to extreme bending moments. The maximum bending moments, measured and calculated for the North Sea environment that were compared with the Class rule minimum requirements.

Present study is to analyse the vertical wave bending moment amidships of the vessel with the two different bow designs. The hydrodynamic loads are calculated with the computer program DNV GL WASIM (2009) based on loading condition summary tables, ship hull offset tables and NAPA database of the vessel. From the loading condition summary tables, one full load condition is selected for the analysis.

Linear calculations using the DNV GL WASIM (2009) are performed to obtain transfer functions of the vertical bending moment amidships of the vessel for the two bow designs. Based on the transfer functions, an irregular wave can be conditioned such that it gives a prescribed linear bending moment at a prescribed time step. The irregular designed wave has been generated to give rule sagging moment. The vertical bending moments are calculated for the vessel in the conditioned waves for the two bow designs in full loading condition using nonlinear WASIM. Vertical bending moments amidships for the two bow designs are obtained as result.

2. Scope of the Work

The scope of work is defined as follows:

- Perform linear WASIM calculations to obtain vertical bending moment transfer functions amidships in full load condition
- Condition irregular incident bow waves so that prescribed bending moment is produced at prescribed time step
- Calculate the vertical bending moment amidships in the conditioned waves for the two bow designs in full load condition with nonlinear WASIM program

3. Main Particulars and Loading Conditions

The vessel's main dimensions are summarized in Table 1.

Table 1. The vessel's main particulars

Length between perpendiculars	191.000 m
Breadth (mould)	23.762 m
Draft (mould)	10.680 m
Depth (mould)	14.850 m

The main characteristics of the analysed loading condition for the ship in head sea are given in Table 2 below. This loading condition is used for both designs.

Table 2. Analysed loading condition

Loading conditions	Displacement	Draft AP	Draft FP	Center of Gravity from AP	GM	Pitch radius of inertia
LC	[tonne]	[m]	[m]	[m]	[m]	[m]
Full load	43932	10.59	10.92	91.75	1.47	43.83

4. Updated Water Lines for Seaworthy Bow

When all WASIM calculations had been completed, updated ship lines because of providing enough buoyancy for seaworthy bow were received. To avoid possible delay of the work, the updated ship lines are compared with the ship lines used in the WASIM geometry calculations. The comparison shows that a slight difference only occurs to one location near the bow as shown in Figure 1. This difference gives 11 tonnes more displacement at bow (the bow would be fuller at that position, which would in turn create more buoyancy), and it tends to increase vertical bending moment amidships for sagging. If only hydrostatic buoyancy is considered, this fuller shape at bow would create an extra amidships vertical bending moment as following;

$VBM_{extra} = mg \times (L_{bp} / 2) = 11 \times 9.81 \times (191/2)$ kNm = 10305.4 kNm

which is about 0.6% of the wave bending moment for the seaworthy bow.

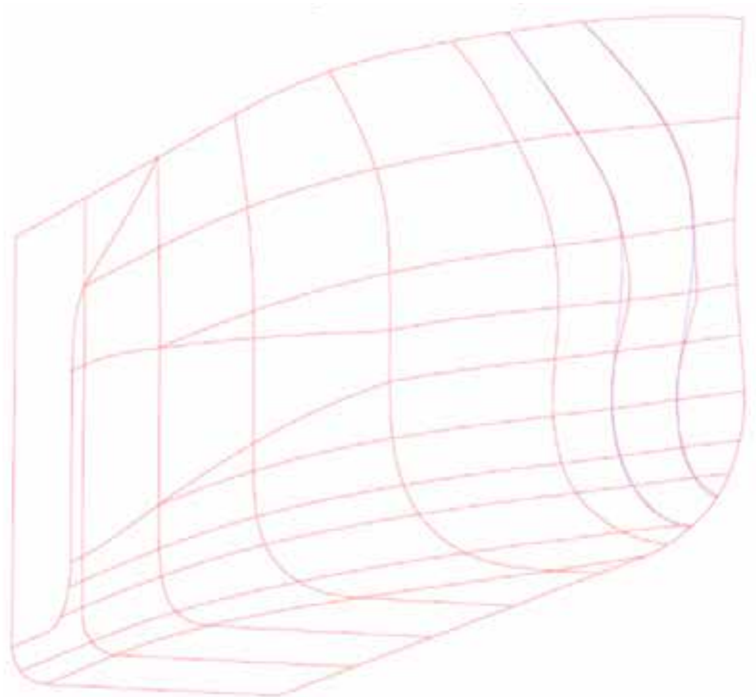

Figure 1. Main difference between updated lines and lines used in WASIM (the blue lines denote the updated ship lines)

5. Hydrodynamic Analysis

The results presented in this study are calculated by use of the WASIM program. WASIM is a linear and nonlinear 3D time domain computer program. The linear version can be used to calculate linear transfer functions while the nonlinear version can be used to simulated nonlinear ship motions in waves. The computer program WASIM (previously known as DNV-SWAN) is a 3-dimensional time domain program for arbitrary shaped ships (including multi-hulls) or other marine structures in waves. The ship may have an arbitrary forward speed, the waves can come from any direction and the responses can be computed in all six degrees of freedom.

The program is based on a three-dimensional Rankine Panel method, where also the free surface is modelled. Radiation conditions are treated by including a zone where the free surface condition is modified such that the waves are absorbed, i.e. a numerical beach on the outskirts of the free surface domain. WASIM was originally developed in a co-operation between Massachusetts institute of Technology and DNV GL.

In the present work, the WASIM version, which is a further development of the SWAN code by DNV, has been applied. WASIM is, in light of the complex problem it solves, a very efficient program. Thus time records of duration of several hours can be obtained with reasonable computational effort. It also benefits from extensive numerical stability analyses done in the early development phase. For this reason the stability is under good control and the program has become very robust. The applied version of WASIM can be run in both a fully linear mode and in a non-linear mode. The implemented non-linear option still solves the linear radiation and diffraction problem. The Froude-Krylov force is calculated by integration of the incident wave pressure over the instantaneous wetted surface of the hull and gives thus a nonlinear contribution. This instantaneous wetted surface is defined by the instantaneous position and orientation of the ship in the incident wave. An additional option is to include slamming loads. A pre-process calculation is then conducted for a set of 2-dimensional strips

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of the hull using the 2DBEM program as developed under the MARIN-CRS research program. These results are subsequently used in the nonlinear WASIM simulation. Thus nonlinear contributions for damping and added mass are incorporated from the above-water-part.

DNV GL WAVESHIP software (2009) efficiently calculates wave motions and loads on ships moving with forward speed, and is based on 2D strip theory, where the roll-damping can be included using the Tanaka model. Viscous damping is tuned by using the empirical methods available in the WAVESHIP program and subsequently used to set the viscous damping in WASIM. The motion equations are solved in an Eulerian frame thus allowing for large amplitude motions. The incident waves are modelled according to linear wave theory. The pressure above the still water level is modelled hydrostatically. The included non-linearities can give significant contributions to both global loads and motions in large waves (Pastoor, 2002).

The sign convention of the motions and co-ordinate system as used in the hydrodynamic calculations is shown in Figure 2. All the co-ordinates mentioned in this report are with respect to a ship fixed co-ordinate system with the x-axis pointing forward, the y-axis pointing to port and the z-axis pointing upwards.

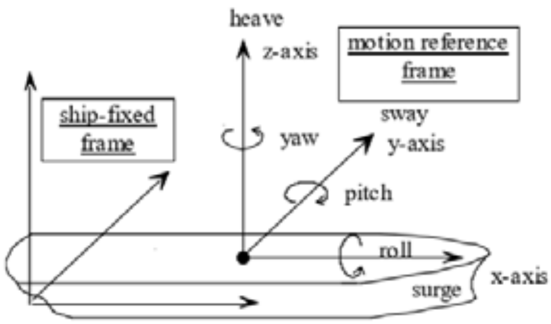

Figure 2. WASIM co-ordinate system and ship fixed co-ordinate system.

6. Geometry and Mass Modelling

WASIM panel model with 60 panels in longitudinal and 20 panels (half ship) in transverse direction is created for the bulbous bow as shown in Figure 3 for an illustration of the mean wetted part of the ship hull as used in the ship motion calculations.

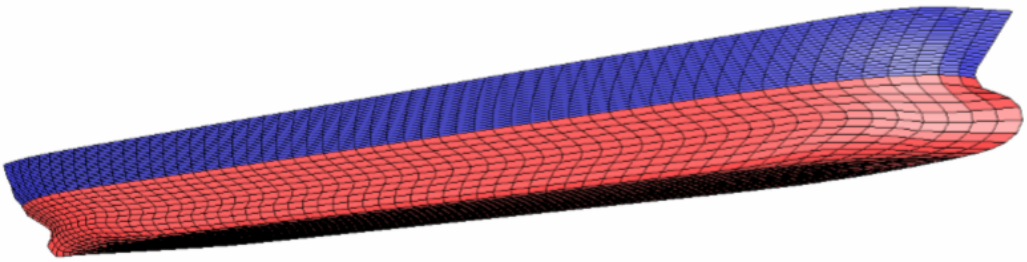

Figure 3. Panel model on ship hull for WASIM calculations (full load, bulbous bow), red part is below calm water surface, blue part is above water surface. Blue part is only used for nonlinear WASIM simulations.

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For the seaworthy bow, the panel model below and above calm water in full load condition is shown in Figure 4 as below.

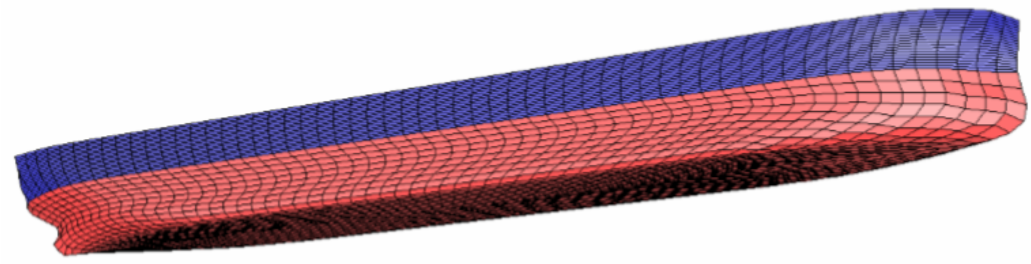

Figure 4. Panel model on ship hull for WASIM calculations (full load, seaworthy bow).

The mass model of the ship is generated by use of the light ship weight distribution tables and cargo weight tables. Some relevant details are given in Table 2 for full load condition of the vessel with the bulbous bow and seaworthy bow.

7. Still Water Bending Moment

By WASIM simulations of the vessel in still water for the two bow designs, the still water bending moment amidships is obtained as given in Table 3 below.

Table 3. Still water bending moment

	Bulbous Bow	Seaworthy Bow
Vertical bending moment (amidships) [kNm]	261,300	268,900

8. Vertical Bending Moment Transfer Functions

Linear WASIM calculations are performed to obtain linear transfer functions for vertical bending moment amidships in full load condition for the vessel with bulbous bow and seaworthy bow. The transfer functions of vertical bending moment amidships are given in Figure 5.

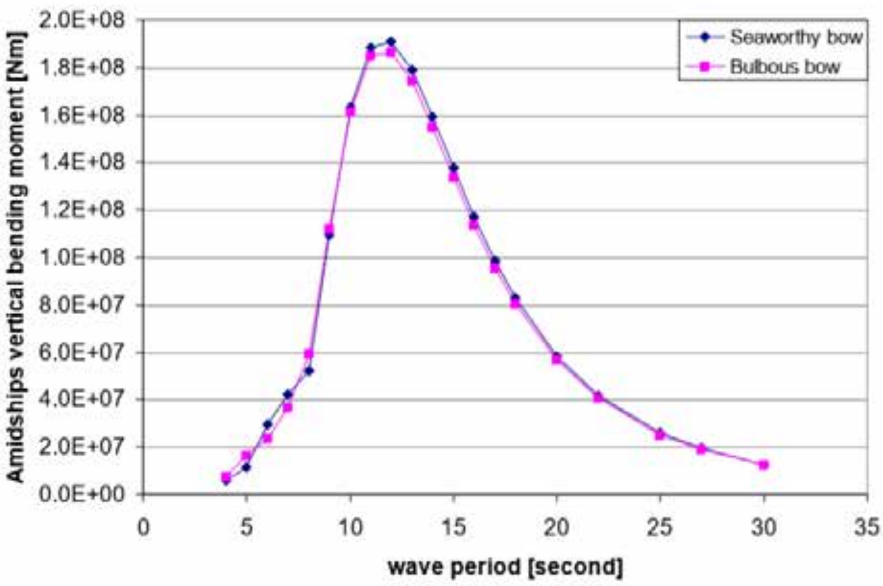

Figure 5. Vertical bending moment transfer function for full load condition in head sea.

9. Irregular Incident Bow Waves Conditioned for Prescribed Vertical Bending Moment

Based on the rule standard vertical bending moment for sagging and the vertical bending moment transfer function shown in Figure 5, an MLER wave (most likely extreme response wave) is generated for the full load condition. The MLER wave is an irregular sea state of short duration, typically 50s, conditioned to produce the linear long term response (in this case the rule value) at a given snapshot. The ship performance in the MLER wave is simulated with nonlinear WASIM in order to calculate the equivalent nonlinear response. Hence, an MLER wave is generated for calculation of wave bending moment responses for full loading condition.

Note that the prescribed time step for the prescribed bending moment is at 35 seconds, and the conditioned extreme vertical bending moment is the rule standard vertical bending moment for sagging plus still water sagging moment, i.e. 1410440 kNm + 261300 kNm = 1671740 kNm (based on the bulbous bow still water bending moment). The design sea state for the MLER wave is given in Table 4 as below.

Table 4. Design sea state for MLER wave

Significant wave height [m]	Zero crossing period [s]	Wave heading
13.0	8.5	Head sea

The plot of the conditioned wave height observed at motion reference point in the full load condition is given in Figure 6.

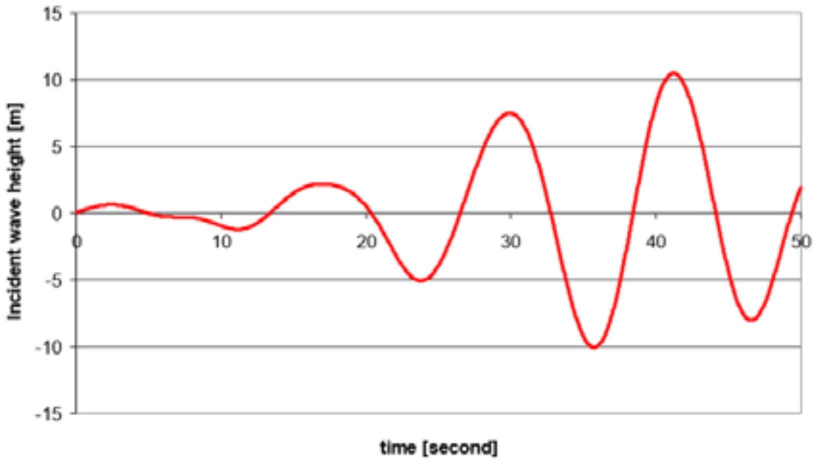

Figure 6. Conditioned wave height time series for full load condition.

The motion reference point is given in Table 5 below.

Table 5. Motion reference point

From AP [m]	From baseline [m]
99.25	8.26

As can be seen from Figure 6, the maximum wave trough is not exactly at time of 35s, this is because the motion reference point is 3.75m forward of amidships.

10. Nonlinear Calculations of Vertical Bending Moment under the Conditioned Incident Waves

The highest responses of wave vertical bending moments amidships for the full load condition of the two bow designs are given in Table 6.

Table 6. Total vertical bending moment in MLER wave

Full load condition (sagging)	
Bulbous bow [kNm]	Seaworthy bow [kNm]
1,894,000	1,945,000

Subtracting the still water bending moment from the total vertical bending moment gives the wave bending moment in the MLER wave for the two bow designs in Table 7.

Table 7. Wave vertical bending moment in MLER wave

Full load condition (sagging)	
Bulbous bow [kNm]	Seaworthy bow [kNm]
1,632,700	1,676,100

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11. Conclusions

WASIM calculations have been performed of the wave vertical bending moment amidships of two bow designs for full load condition. The two designs mainly differ from each other in bow shape. Comparison is made between the amidships vertical bending moment of the vessel with the two designs in the same MLER wave for full load condition.

- Transfer functions of the vertical bending moment amidships of the vessel with both the bulbous bow and sea worthy bow are obtained for full load condition in head sea.
- An MLER wave is generated for full load condition based on the transfer functions, the rule value of the vertical bending moment and the possible 20 years extreme waves in the North Atlantic Ocean.
- Nonlinear calculations of the vertical bending moment amidships of the vessel with the bulbous bow and the seaworthy bow in the MLER waves have been performed for the full load condition.
- The highest wave vertical bending moment (sagging) amidships of the vessel with the seaworthy bow for the full load condition is 2.6% higher than the counterpart value of the vessel with the bulbous bow.

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