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Finite Element Simulation of a Mercantile Vessel Shipboard Under Working Conditions

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Abstract

Despite the availability of other transport methods such as land and air, marine transportation is the most preferred and widely used transportation method in the world because of its economical advantages. Due to the economical advantages, ship based studies have gained importance especially in recent years.
In order to design safe, ergonomic and at the same time economic ships or vessels, both numerical and experimental methods have to be taken into account. Large-scale structural modeling like the cases in ships, on the other hand, typically relies on Finite Element Analysis (FEA) techniques. With the widespread use of Finite Element Methods (FEM) in the field of Computer Aided Design (CAD) engineering, it is possible to increase the strength of a mercantile vessel shipboard.
As a consequence, in this study, the strength of a mercantile vessel shipboard has been investigated under working conditions by using ANSYS package program. The results of this study can provide the designer with some guidelines in designing shipboard of mercantile vessels.

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Keywords: Mercantile vessel shipboard; Finite Element Analysis (FEA); Static strength

1. Introduction

The durability of a ship structure can be defined as the ability of the structure in order to maintain its mechanical performance through its service life. Hence, there are close relation between durability and safety. In marine structures such as ships, mercantile vessel shipboards and offshore platforms, damage is mainly due to static and

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fatigue loads. Hence, ships have to be analyzed according to different types of loading, which are static and fatigue, in order to design safe and reliable structures.

In literature, there are many experimental or numerical studies related to marine based structures [1-7]. However, most of the studies have investigated either a parameter in the structure like material [1] and joint type [2, 3], or some parts of the structure [1-4], but little attention has been paid to the analysis of the whole structure [6, 7].

Kim and his colleagues have investigated mechanical properties of steel of a commercial ship considering low temperature effects to the material used in the body of the ship. They have found that temperature has a considerable effect on material strength and fracture strain behavior [1]. The relation between static overload and fatigue strength considering welding process has been analyzed. For this case, prototypes have been constructed and fatigue tests have been conducted using the so called specimens, that is prototypes. It has been found that there is a close relation between the welding type and fatigue of the structure [2]. Again using some experimental results, fatigue strength of the welded structural parts of the ship body has been calculated. In this study, the effects of different approaches on specimens and joint types have been investigated [3]. In [4], five different model have been tested to define fatigue strength. In these models, the attention has been paid to the geometric properties of the ship structures and as a result the effects of the geometric properties of the selected models on fatigue behavior have been investigated.

Due to the complex natures of ships, generally some parts of the structures are chosen in analyses instead of full structure. For example, fatigue strength of hull structural elements of sea-going ships has been examined by using and comparing different fatigue approaches [5]. However, there are a few works [6, 7] which consider whole structure of ships. In these studies, generally the existing fatigue life prediction approaches have been compared either using different ship models obtained numerically [6] or using both experimental test results and also some numerical data [7].

Studies on ship structures have mainly focused on numerical work due to the complexity of the structures. It is important to note that while experimental studies provide the necessary physical insight, predictive tasks such as design, analysis and evaluation of ship structures are often carried out by computational methods. Ship structures present several challenges to design engineers in terms of mechanical analysis and evaluation of the details of the structures like stiffeners. First of all, depending on the quality, ship structures can fail either through the constructional components like stiffeners or through the hull (there is a certain uncertainty involved). Secondly, because of geometrical complexity of ship structures, effective correlation between the mechanical performance of the constructional components and the stress and deformation fields around these components is difficult from experimental results. For example, the stress distribution hence fracture mechanism in the bulb flat cannot be fully understood from experimental results. Hence numerical methods have advantages over experimental methods in terms of especially stress distribution and fracture mechanism.

As a consequence, in this study, the strength of a mercantile vessel shipboard has been analyzed numerically considering working or service conditions. Due to its strong solver, ANSYS [8] package program was chosen as Finite Element Analysis (FEA) tool in the present study.

2. Model details

Model details of the structure analyzed in this study can be divided into two parts. These are material and geometric properties.

2.1. Material properties

In general, steels which are used in ship building can be divided into five categories, Grades A, B, C, D, and E. Among the steels, Grades A and B of mild steel have been used [1]. In this current study, Grade A steel material was chosen because this kind of material is widely used in ship hull structures. Table 1 lists material properties of Grade A steel.

2.2. Geometric properties

Table 2, on the other hand, shows geometric properties of the ship structure (barge) considered in this study. The so called properties have been defined according to Turkish Lloyd Rules [9].

Table 1. Material properties of Grade A steel.

Material property	Corresponding value
Young modules (GPa)	260
Poisson's ratio	0,3
Density (tone/mm^3)	7,85 10^{-9}

Table 2. Geometric properties of the barge.

Geometric property	Corresponding value
Full-length (L) (m)	135,8
Width (B) (m)	42
Depth (m)	8
Draft (m)	5,4
Block coefficient (C_B)	0,95
Barge speed (knot)	3
Wave coefficient	6,4253
Service type coefficient	0,75
Length coefficient	1
m = Sagging coefficient/Hogging coefficient	0,9944
Material factor	1

3. FE Analysis details

3.1. Calculation of forces used in FE analysis

Because the aim of this study is to investigate the behavior of the ship structure under working conditions in terms of static loads, firstly the loads have to be defined. In FEA of the ship structure, it has to be considered two fundamental loads corresponding to the sagging and hogging cases which are known as vertical shear forces. According to Turkish Lloyd Rules [9], vertical shear force can be calculated using Equation (1);

$$Q_{WV} = C_W\, C_B\, L\, B\, (C_B + 0.7)\, C_Q \tag{1}$$

here, Q_{WV} represents the so called vertical shear force; L and B are the length and width of the ship, respectively; C_B and C_W shows block and wave coefficients, respectively. The aforementioned constants have been defined according to Turkish Lloyd [9] as 0.95 and 6.4253, respectively. Finally, C_Q represents dissipation factor. C_Q has different values depending on the distance on the deck and position of the ship inside of the sea. Substituting these coefficients result the so called forces for sagging and hogging used in this study.

3.2. Model Description

For dynamic and nonlinear static analyses (in this study, due to the contact elements, nonlinearity was present) etc., it is not reasonable to apply symmetry conditions arbitrarily, including both geometry symmetry wherever possible to decrease model size and loading symmetry. Hence, it has been used full shape (not symmetric model) of the ship structure, that is barge, in numerical analysis done by ANSYS package program.

Because, the structure is big, it is not logical to use Solid as the element type in this study, so SHELL 181 has been adopted as the element type in order to mesh the structure.

In addition, the material used for the structure has been assumed to be homogeneous, isotropic and linearly elastic; large deformation, which is not the case in ship building, has not been considered.

3.3. Boundary conditions

Because static analysis has been performed, the bottom surface of the ship structure has been clamped, that is displacements and rotations have been set to zero. This constraint has been applied because it has been aimed to obtain a similar situation to the conditions of working condition.

As far as loads are concerned, pressures were applied on the upper surface of the ship structure. Because the distributions of nodes on the so called surface are not homogeneous due to the modelling of the structure, it has been used pressure instead of load directly just to create homogenous pressure on the surface of the ship structure.

3.4. Meshes

Using the above explanations, the finite element meshes of the ship structure have been created. The total number of elements and nodes are 59778 and 53367 respectively in the structural model. Finer meshes have been introduced near to the edges of bulb flats.

3.5. Analysis

After modeling and meshing the so called ship structure using the above material data and techniques, two different loads have been applied on top surface of the ship structure of magnitudes of 16100 kN and 4584 kN which are the maximum and minimum loads representing sagging and hogging cases, respectively.

Detailed three-dimensional stress variations considering the full shape have been obtained after finite element analysis fulfilled via ANSYS 14 as shown in Figures 1-4. These stress variations can be used to provide the so called strength of the ship structure under sagging and hogging cases which are the most critical loads.

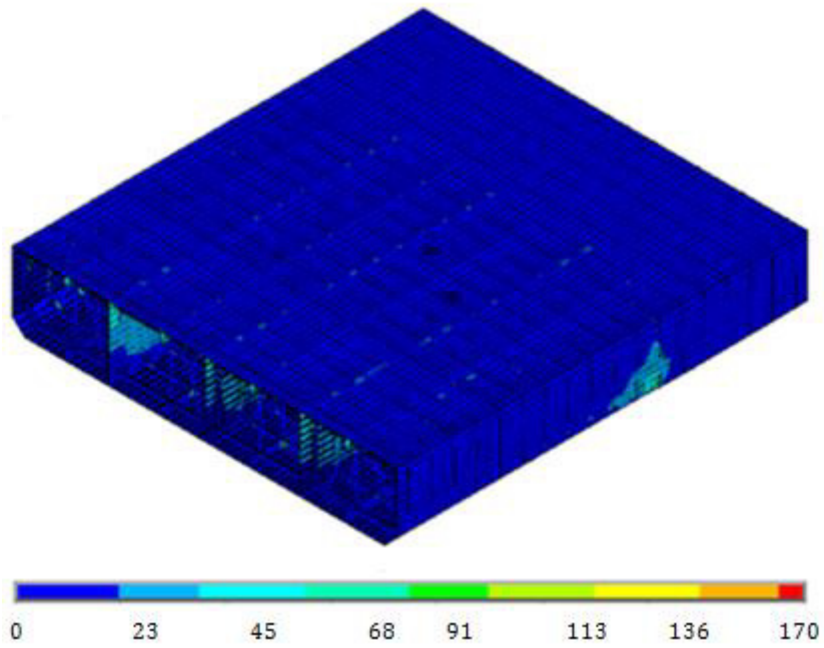

Fig. 1. von Mises stress distribution of the ship structure (barge) for sagging case [10].

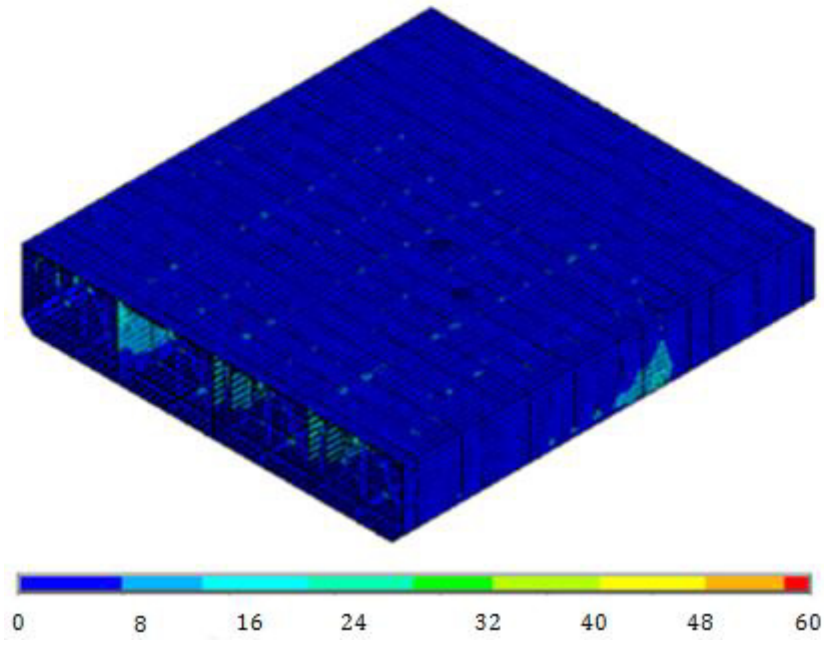

Fig. 2. von Mises stress distribution of the ship structure (barge) for hogging case [10].

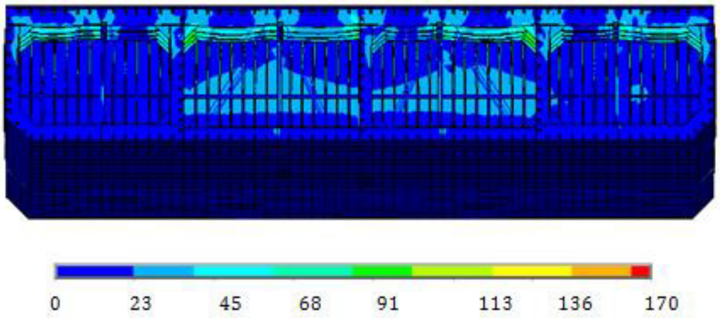

Fig. 3. von Mises stress distribution of the ship structure (barge) for sagging case (focused on the side region) [10].

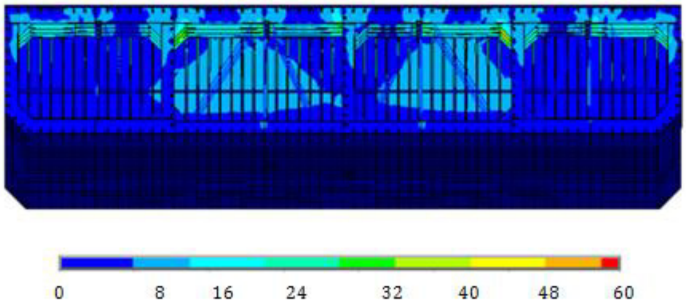

Fig. 4. von Mises stress distribution of the ship structure (barge) for hogging case (focused on the side region) [10].

3.6. Assessment of FEA study

A detailed study of the three-dimensional Finite element solutions of the stress fields in the ship structure (barge) has been obtained.

Global views of the stress distributions, von Mises, in the ship structure (barge) for sagging and hogging cases are shown in Figures 1-4. As seen in these figures, load transfer in the ship structure (barge) is mainly accomplished by the material near the boundary of the stiffeners, bulb flats (Holland profiles) while the rest of the structure is mostly stress-free which proof why the designs of stiffeners in a ship structure are important.

It is clear from the finite element analysis that a stress concentration or singularity exists at the interception of the bulb flats with the joined sheets because all von Mises stresses have their maximum magnitudes at the so called regions. These stress distributions explain successfully the phenomenon that why the fractures are generally first created at the connections of bulb flats and ship body sheets.

4. Conclusion and recommendations

In this study the working conditions of a ship structure (barge) were investigated numerically. Finite element analyses were carried out taking into account nonlinear constitutive relations, plastic deformation, and residual stresses to determine the stress states, von Mises stress distribution, in the structure under static loads which were the forces representing sagging and hogging cases. As expected, high stresses were found close to highly localized regions, e.g. bulb flats. So, the results of this study can provide designers with some guidelines in designing shipboard of mercantile vessels. However, further study of the fatigue strength assessment of ship structures is required.

References

[1] D.K. Kim, D.K. Park, J.K. Seo, J.K. Paik, B.J. Kim, Effects of low temperature on mechanical properties of steel and ultimate hull girder strength of commercial ship, Korean J Met Mater. 50 (2012) 427-432.
[2] S.J. Park, H.W. Lee, A study on the fatigue strength characteristics of ship structural steel with gusset welds, Int J Nav Arch Ocean Eng. 4 (2012) 132-140.
[3] C.M. Rizzo, R.A. Tedeschi, Fatigue strength of a typical ship structural detail: tests and calculation methods, Fatigue Fract Eng M, 30 (2007) 653-663.
[4] J. Kozak, Z. Gorski, Fatigue strength determination of ship structural joints Part I Analytical methods for determining fatigue strength of ship structures, Pol Marit Res. 18 (2011) 28-36.
[5] W. Fricke, S. Zacke, M. Kocak, S.E. Eren, Fatigue and fracture strength of ship block joints welded with large gaps, Welding in the world. 56 (2012) 30-39.
[6] W. Fricke, A. von Lilienfeld-Toal, H. Paetzold, Fatigue strength investigations of welded details of stiffened plate structures in steel ships, Int J Fatigue. 34 (2012) 17-26.
[7] W. Fricke, H. Paetzold, Full-scale fatigue tests of ship structures to validate the S-N approaches for fatigue strength assessment, Mar Struct. 23 (2010) 115-130.
[8] ANSYS Documentation, ANSYS v. 14, 2013.
[9] Turkish Lloyd Rules, 2013.
[10] A.F. Yilmaz, Fatigue analysis of the ship structure made of Holland profiles (in Turkish), M.Sc. Thesis, Karabuk University, 2013.