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LOCAL STRUCTURAL ANALYSYS OF POTABLE WATER SYSTEM FOUNDATION

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ABSTRACT

This paper presents the local structural analysis of a steel foundation supporting the pumps of a potable water system installed on a 30,000 DWT Handymax bulk carrier. The aim is to evaluate the structural behaviour of the foundation under static and dynamic loads representative for shipboard service and to propose simple constructive improvements that enhance stiffness and vibration performance. The potable water system is briefly described, including design requirements, sizing of the pumps, hydrophore unit and heat exchanger. The support structure is modelled in 3D CAD and analysed using the finite element method in ANSYS Mechanical, considering the mass of the pump unit and excitation frequencies up to 60 Hz. Three foundation variants are investigated: the initial design, a stiffened version obtained by adding local reinforcements and an alternative closed-section frame using rectangular hollow profiles. For each model, deformations and equivalent von Mises stresses are evaluated and compared with the yield limit of steel S235JR and with serviceability criteria from Eurocode 3. The results show that the optimized foundation with rectangular hollow sections significantly reduces maximum deformations and improves dynamic behaviour, without exceeding allowable stress levels. Recommendations for monitoring, maintenance and vibration isolation using spring-type anti-vibration mounts are also formulated.

Keywords: potable water system, ship structure, pump foundation, finite element method, ANSYS, vibration

1. INTRODUCTION

Structural analysis is a key stage in the engineering design of ship structures and their local foundations. It allows designers to determine the effects of mechanical, thermal or dynamic loads on structural components and to ensure safety, reliability and adequate service life. Using concepts from applied mechanics, material science and applied mathematics, the analysis provides internal forces, stresses, deformations and stability indicators for structural members and assemblies.

The objective of this study is the local structural assessment of a steel foundation supporting two potable-water pumps on board a 30,000 DWT bulk carrier. The analysis focuses on: verification of local strength, identification of stress concentrations, evaluation of deformations under dynamic excitation and comparison of alternative design configurations. Numerical simulations are carried out with the finite element method (FEM) in ANSYS, providing a rational basis for design optimization and for defining monitoring and maintenance measures.

2. POTABLE WATER SYSTEM

The analyzed ship is a Handymax bulk carrier with a deadweight of 30,000 t, fitted with five cargo holds and a conventional single-screw propulsion plant. The main dimensions are LOA = 170 m, LPP = 162.2 m, B = 27 m, D = 14.5 m, T = 10 m, service speed ≈ 14.5 kn.

The potable water installation provides fresh water to accommodation spaces, galley, sanitary blocks and medical facilities. Water can be supplied either from shore or produced on board by a fresh-water generator, then stored in dedicated stainless-steel tanks and distributed by pumps and a hydrophore unit through a closed pipe network.

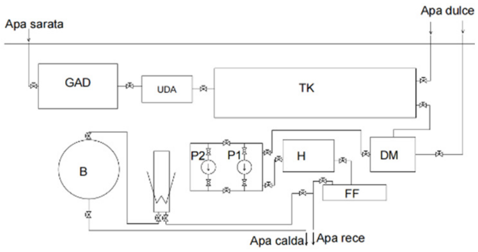

Fig.1. Potable Water System Diagram

The system includes fresh-water generator (GAD), de-aeration unit (UDA), storage tank (TK), boiler (B), two centrifugal pumps (P1–P2), hydrophore (H), dosing unit (DM), final filter (FF) and a plate heat exchanger.

Design of the system follows IMO, WHO and EU requirements, as well as classification society and ISO standards for potable water on ships (e.g. ISO 15748). These regulations cover separation from other pipe systems, material selection for tanks and pipes, prevention of contamination, pressure and temperature ranges and redundancy of essential equipment such as distribution pumps.

The daily water consumption is estimated considering 20 persons on board and 150 l/day per person, resulting in 3 m^3/day and a total of 60 m^3 for a 20-day autonomy. Based on the number of consumers (showers, washbasins, toilets) and simultaneity coefficients, the required pump flow rate is about 10 m^3/h. The minimum supply pressure, determined from static head, head losses and required pressure at consumers, is around 4.8 bar. This leads to the selection of a multi-pump unit similar to the Hydro MPC-E-2-CRIE-2-04 configuration, which complies with the calculated duty point.

3. FOUNDATION MESHING

The foundation is a welded steel structure that supports the twin-pump unit and transfers loads to the ship's deck through anti-vibration mounts. Its main tasks are to provide a stable base, to distribute loads safely to the foundation and to limit vibrations to acceptable levels.

3.2. Initial foundation model

The initial design consists of longitudinal and transverse flat plates welded together according to classification society rules for fillet weld sizes. The overall dimensions are approximately 1500 × 580 mm with a height of 56 mm. The 3D geometry is created in AutoCAD and exported in STEP format to ANSYS Workbench. The pump unit (two pumps and common base) has a mass of about 315 kg and is represented by a concentrated mass applied on the top plates in the region of the pump feet.

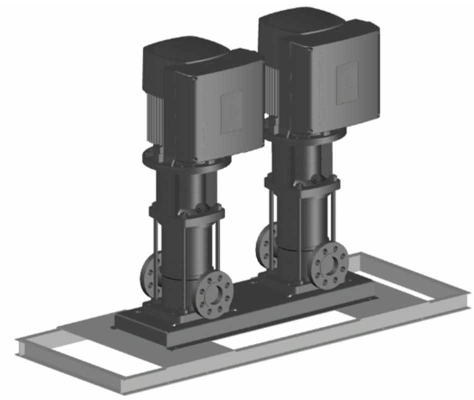

Fig.2. 3D model of the pump's foundation

3.3. Material properties and meshing

All foundation variants are made of structural steel S235JR with Young's modulus E ≈ 210 GPa, Poisson's ratio ν = 0.3 and yield stress fy ≈ 235 MPa. A solid finite-element mesh is generated automatically and refined manually near the plate edges, cut-outs and fixing holes. Typical element sizes are 5–10 mm in low-gradient regions and 1–3 mm in highly stressed areas, providing a balance between accuracy and computational cost.

Boundary conditions reproduce the bolted connection to the vibration isolators, which are assumed fixed in all degrees of freedom at their interface with the foundation. The pump mass is applied as a point mass with gravity acting in the negative Z direction.

3.4. Alternative designs

Based on the results of the initial analysis, two design improvements are studied:

- Optimized plate foundation: stiffeners are added below the pump seating plates to increase local rigidity. They are welded to the top plates and longitudinal members, using the same steel grade.
- Rectangular hollow-section foundation: the frame is rebuilt from closed box profiles 50 × 50 × 5 mm, forming a lattice of longitudinal and transverse members supporting the pump plates. The main dimensions (length, width, height) are kept similar to the original solution.

For all variants, harmonic response analyses are performed for excitation frequencies of 40 and 60 Hz, representing typical operating range of the pumps.

4. RESULTS AND DISCUSSION

4.2. Deformations under dynamic excitation

For the initial foundation, the maximum total deformation at 60 Hz reaches about 2.91 mm, occurring near the centre of the pump plates. At 40 Hz the maxima are roughly 1.24 mm, respectively, showing decreasing response away from the main excitation frequency.

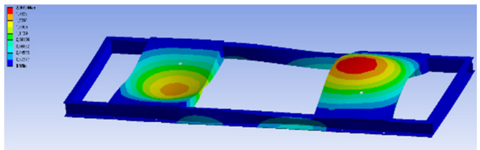

Fig.3. Deformation plot, 60 Hz, initial

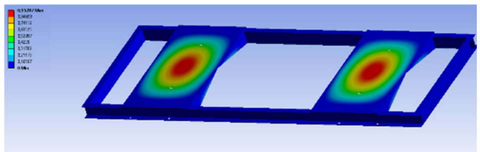

Fig.4. Deformation plot, 40 Hz, initial

After adding local stiffeners (optimized plate foundation), the maximum deformation at 60 Hz reduces to about 2.01 mm, and to about 0.95 mm at 40 Hz, while the deformation pattern remains similar.

The rectangular hollow-section foundation provides the best performance, with a maximum deformation of approximately 1.98 mm at 60 Hz and only 0.33 mm at 40 Hz, i.e. significantly lower than in the previous configurations. The deformation shapes are smoother, indicating a more uniform stiffness distribution along the frame.

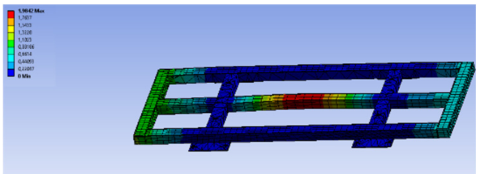

Fig.5. Deformation plot, 60 Hz, reinforced

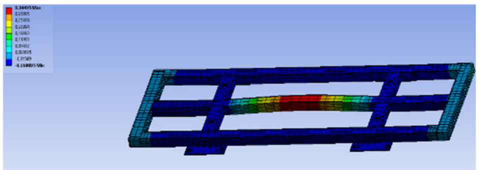

Fig.6. Deformation plot, 40 Hz, reinforced

The reduction of deformations by about 31–47% compared to the initial design improves both structural safety and functional behaviour of the pumps, decreasing misalignment risk and dynamic loads on bolts and welds.

4.3. Stress levels and safety criteria

Equivalent von Mises stresses in all models remain below the yield limit of S235JR (≈235 MPa), satisfying strength criteria for the considered load cases. Serviceability is checked using Eurocode 3 recommendations, which limit deformations to about L/250 for beams supporting sensitive equipment. For a characteristic length of 1500 mm, this corresponds to a limit of 6 mm, so the computed deformations in all variants are well within allowable values. Modal analysis indicates that the first natural frequency of the optimized models is higher than 60 Hz, which reduces the risk of resonance with the pump operating frequency. These elements provide elastic support, allowing controlled displacements while attenuating dynamic forces transmitted to the deck.

5. CONCLUSIONS

The local structural analysis of the potable-water pump foundation on a 30,000 DWT bulk carrier has demonstrated the importance of combining FEM simulations with simple constructive modifications to achieve safe and efficient support structures.

The initial foundation satisfies stress limits but exhibits relatively high dynamic deformations (up to ≈2.9 mm at 60 Hz) with deformation maxima under the pump seats. Introducing local stiffeners below the pump plates reduces maximum deformations by more than 30% and leads to a more favorable distribution of stress and deformations.

Replacing open plates with a closed rectangular hollow-section frame results in the most rigid configuration, with the lowest deformations and higher natural frequencies, while maintaining stresses below the yield limit of S235JR and within Eurocode 3 serviceability criteria. The optimized foundation ensure reduced vibration transmission to the hull, improved durability of welds and bolts and increased reliability of the potable water system.

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