Marine Structural Engineering (MMA168)

General Stress Analysis of a Beam Girder

Assignment 2

(Due on 2019-12-06)

1. Background

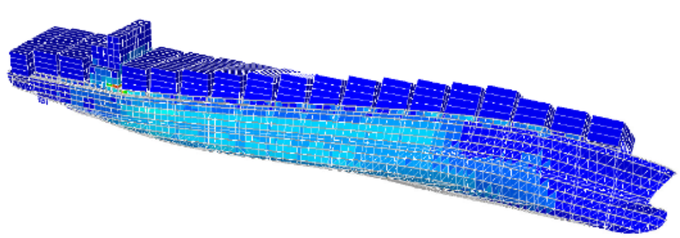
Engineering beam theory is a powerful tool that can be used to determine the approximate stress response of a marine structure through simple and fast calculations. In this course, we teach you how to use this theory on simplistic examples that are suitable for hand calculations. In the industry, similar hand-calculations are often made before more advanced analyses, such as finite element analyses, are carried out.

2. Purpose

The purpose of this assignment is to make you more comfortable with making general stress analysis of typical marine structures. The calculations you are going to do are normally carried out in parallel with the development of large-scale finite element models to ensure that the resolution of the finite element models is sufficient.

3. General information

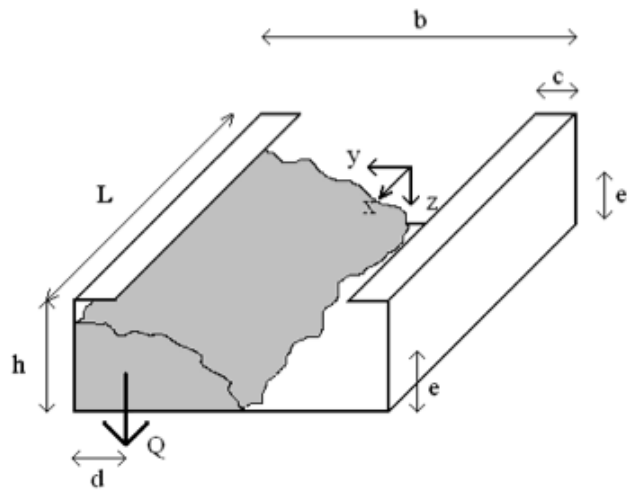
In this assignment, you will determine with engineering beam theory the normal stress response of a ship structure with an open cross-section. Bulk carriers and container vessels are examples of ship types that have open cross-sections. When these type of structures are subjected to bending and torsion loads, normal stresses arise due to bending and warping displacements. The figure below shows the exaggerated deformation behavior of a container vessel. In the figure, the warping displacements amidships can be clearly seen.



In this assignment, a bulk carrier that has gone through some heavy weather will be used as the case study. In one compartment, the cargo has shifted, giving an unfavorable loading condition (see the figure below). Assume that the compartment is rigidly fixed in its ends (i.e. you should disregard global bending of the other parts of the ship) and that distributed load, Q is acting in the centre of gravity of the cargo at a distance d from the starboard of the ship. The distance from the bottom to the neutral axis is e and the moment of inertia around the neutral axis is I_y. K_v is the St. Venant's torsional constant, and the coordinate system (x, y, z) lays on the neutral axis and on the plane of symmetry of the cross-section.

Initial data:

- $Q = 150\times10^3$ kg/m
- $L = 45$ m
- $b = 30$ m
- $h = 12$ m
- $c = 6$ m
- $d = 4$ m
- $t = 25$ mm
- $e = 4.36$ m
- $K_v = 1.031\times10^{-3}$ m^4
- $I_y = 40.58$ m^4



4. Tasks

The same *football teams* of Assignment 1 are asked to:

1. Calculate, for the ship cross-section *in the appendix*, the vertical distance between the keel and the neutral axis e and the moment of inertia about the neutral axis I_y.

   Today, commercial software can be used to calculate these two values, but a naval architect should also be able to calculate them by hand or by systematically applying the parallel axis theorem (aka. Steiner's theorem). The cross-section in the appendix is a typical cross-section of a 4,400 TEU container vessel, and it was chosen because it is a good example to practice on. *These two values will not be used further in this assignment.*

2. *With the initial data*, calculate the normal stresses throughout the cross-section and along the ship for each of the different load components (bending, torsion, etc.). For each loading contribution, draw at least two diagrams showing the distribution of normal stresses throughout the cross-section at a section along the compartment. In each of the diagrams, you must indicate the exact locations where the normal stress is zero.

3. With the results from Task 2, determine the location and absolute value of the maximum normal stress. Draw a diagram of the distribution of *total* normal stresses throughout the cross-section at a section along the compartment where the absolute maximum normal stress is found.

4. (optional) Vary the length of the compartment from 30 m to 60 m (in steps of 2 to 5 m, your choice). Present diagrams showing how the following parameters are affected by the change in compartment length:

   - The maximum bending moment M_y^{max}.
   - The mixed torsion parameter α.
   - The maximum normal stress for each load component (σ_b^{max}, σ_ω^{max}, etc.).
   - The maximum absolute total normal stress σ_T^{max}
   - The ratio $\sigma_b^{max}/\sigma_\omega^{max}$ at the location of the maximum absolute normal stress.
   - The location of the maximum absolute normal stress.

   For each of these parameters, you should briefly describe the reason behind the observed changes in a non-trivial way, for example: "The observed changes are because the length of the compartment changed." Discuss briefly the implications in the design of marine structures.

5. (optional) Stress-based fatigue analysis can be carried out with the Basquin equation, $\Delta\sigma_a = C(N_f)^{-m}$, where C and m are material constants, $\Delta\sigma_a$ is the stress amplitude, and N_f is the number of reversals (cycles) to fatigue failure. Taking the maximum absolute total normal stress calculated in Task 4 as $\Delta\sigma_a$, use the Basquin equation to determine the number of cycles to failure. Use $m = 1/3$ and C = 9900 MPa. Present a diagram of how N_f changes with the compartment length. Discuss briefly the implications in the design of marine structures.

5. Details

The deliverable of this assignment is a technical report, for which the audience is an *experienced* naval architect. Since the report is for a professional, you may use technical language, and you must be clear and *concise*. Note that a concise text is not necessarily a short text.

The report must have the following basic structure:

- Title
- Authors
- Introduction: Brief description of the study case, the loading conditions, and the assumptions regarding the boundary conditions.

- Task 1: Statement of the theory used to complete the task and the calculation method. Clear statement of the results. Brief discussion of the accuracy of the results.
- Task 2: Statement of the theories used to complete the task and the calculation method. Clear statement of the results (good quality readable diagrams). Brief discussion of the accuracy of the results.
- Task 3: Clear statement of the results (good quality readable diagrams). Brief discussion of the accuracy of the results (consider the fundamental requirement of the superposition principle).
- Task 4 (optional) Clear statement of the results (good quality readable diagrams). Brief descriptions for the observed changes, and brief discussions on the implications in the design of marine structures.
- Task 5 (optional) Clear statement of the results (good quality readable diagrams). Brief descriptions for the observed changes, and brief discussions on the implications in the design of marine structures.
- Appendix: Additional images and MATLAB code if any.
- References: Compendium and others if applicable.

6. Evaluation

To pass this assignment you must provide correct answer for Tasks 1, 2 and 3.

Submit your report by e-mail to Shunhan.Yang@chalmers.se.