Probabilistic Damage Stability - Evaluating the Attained Subdivision Index for a Special Purpose Ship by Analysing the Effect of Changes in the General Arrangement and Loading Conditions

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salt SHIP DESIGN

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Introduction

A ship's damage stability heavily depends on the internal watertight arrangement of the ship. Since January 1st 2009, the probabilistic damage stability (PDS) regulations (SOLAS-2009) apply to cargo ships above 80 m in length, passenger ships and Special Purpose Ships (SPS). The probabilistic approach is based on damage statistics from ship collisions. Consequently, the PDS regulations offer more flexibility in design in terms of internal subdivision of watertight bulkheads, as compared to the deterministic regulations prevailing pre-2009. In shortness, the ship's damage stability will be approved by the relevant authorities if the following IMO requirement is fulfilled:

$$\textbf{Attained index } A = \Sigma P_i S_i V_i > 0.4A_S + 0.4A_P + 0.2A_L > \textbf{ Required index R}$$

A_S, A_P and A_L represent the three different loading conditions d_S, d_P and d_L, which the ship operates in 40%, 40% and 20% of the time, respectively, according to SOLAS. In a damage case, the factors P_i, S_i and V_i represent the following three probabilities, respectively: longitudinal location and transverse penetration depth, survivability of the ship, and whether certain decks limit vertical flooding or not. These factors are calculated for all damage zones that the ship is divided into. Damage zones are usually restricted by watertight bulkheads and decks.

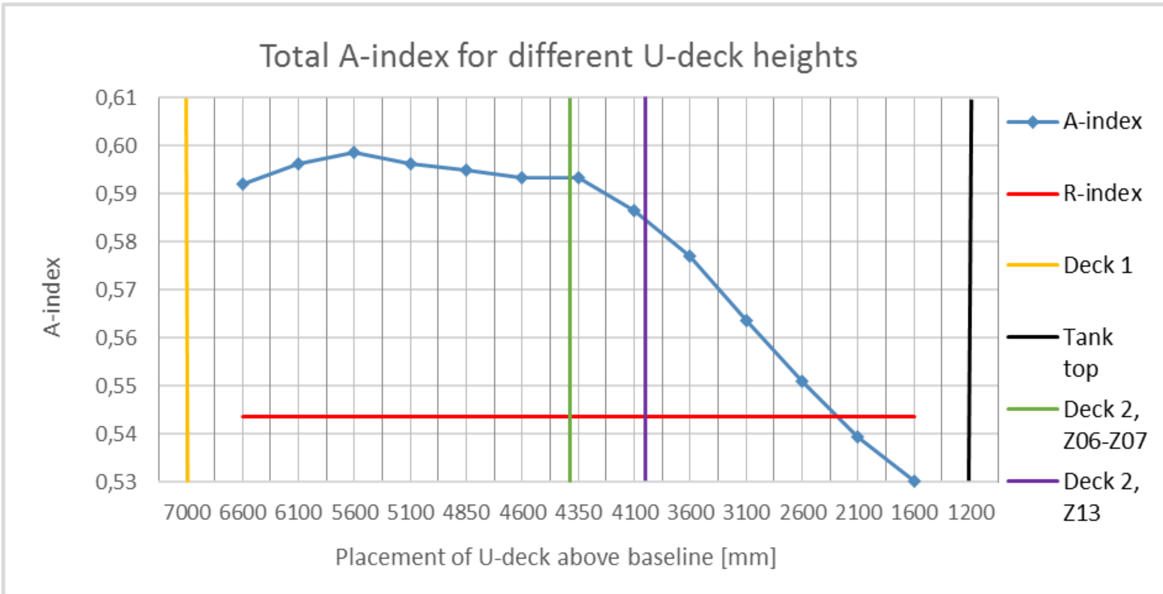
Objectives

How can the ship designer take advantage of the flexibility that the PDS regulations provide?

Software

The market leading stability software NAPA was used to model the ship and carry out intact and probabilistic damage stability (PDS) calculations. The PDS calculations are done according to SOLAS Ch. II-1 Part B-1 Stability. Since NAPA licenses are costly, it was not easy to get hold of a license. The author would therefore like to thank Salt Ship Design for providing one.

Results

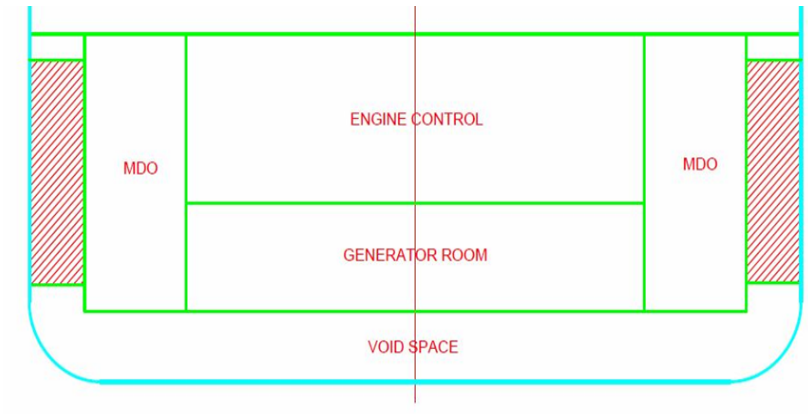


First of all, the goal is usually to maximise the attained index A to increase safety, without reducing the «performance» of the ship in any way. Due to the top-down design approach that is widely used today, the watertight subdivision is determined at late design stages. Therefore, the abovementioned goal is often limited by time pressure; using optimisation tools to maximise A is challenging, thus the designer normally relies on experience. In co-operation with Salt Ship Design, the following two objectives have been investigated in the master thesis so far:

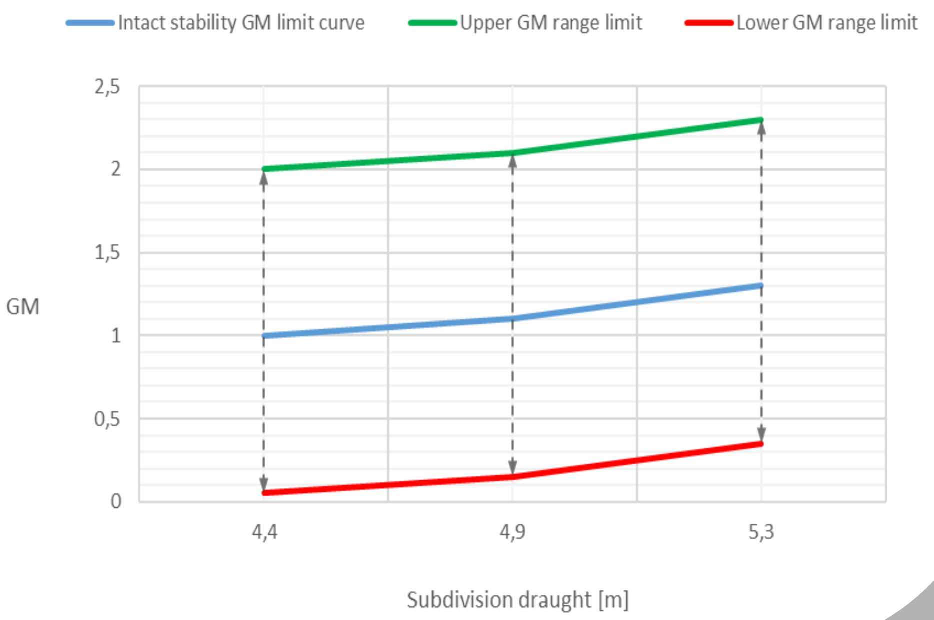
1. Investigate the effect of changing the height of the deck (U-deck) that separates the void U-tanks and wing ballast tanks at the mid-section of a Wind Farm Service Vessel designed by Salt Ship Design.
2. Investigate the effect of changing the intact stability of the ship, i.e. the ship's GM (or KG) value, for the different subdivision draughts.

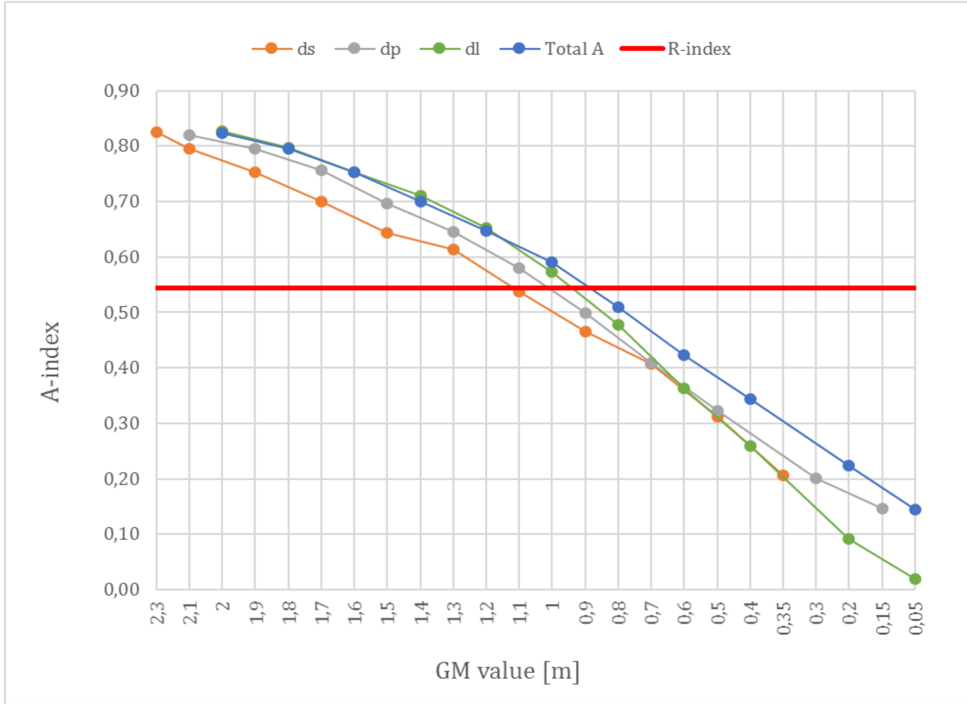
Method

The figure to the right illustrates how objective 1 has been investigated: the U-deck is moved from the tank top up to deck 1 with an interval of 0.5 m at first. To get more accurate results in relevant areas, i.e. areas where there is a reasonable trade off between large A value and sufficient amount of ballast water, shorter intervals are used.



For objective 2, the graph to the right illustrates the approach that has been used: calculations where GM ranges approximately from 0 m to 2 m with an interval of 0.2 m are carried out for all three subdivision draughts (d_S, d_P and d_L).





Conclusions and Further Work

The two figures presented above show clear tendencies. Both the lower the U-deck height goes and the lower the GM value goes, the lower the attained index A becomes for the Wind Farm Service Vessel used in this study. Most likely, these results are also valid for similar offshore vessels. Regarding further studies, other GA configurations could be investigated with respect to the effect of changes on the attained index A.

References

The most important references used in the master thesis are listed below:

- IMO. (2006). SOLAS Chapter II-1 Construction - Structure, Subdivision and Stability, Machinery and Electrical Installations, Part B-1 Stability.: International Maritime Organization.
- IMO. (2008c). Resolution MSC.281(85), Explanatory notes to the SOLAS Chapter II-1, Subdivision and damage stability regulations, Part B.: International Maritime Organization.
- NAPA. (2015). NAPA for Design Manuals 2015.3
- Djupvik, O. M., Aanondsen, S. A., & Asbjørnslett, B. E. (2015). Probabilistic Damage Stability - Maximizing the Attained Index by Analyzing the Effects of Changes in the Arrangement for Offshore Vessels: NTNU.