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A simplified method to predict grounding damage of double bottom tankers

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ABSTRACT

This paper presents a set of analytical expressions for the calculation of damage opening sizes in tanker groundings. The simplified formulas were given for the grounding force, longitudinal structural damage and the opening width in the inner and outer plating of a tanker's double bottom. The simplified formulas derived are based on a set of numerical simulations conducted with tankers of different dimensions- 120, 190 and 260 m in length. The simulations were performed for five penetration depths and for several rock/ground topologies.

The formula for the horizontal grounding force was derived provided the grounding force is proportional to the contact area and the contact pressure. By use of regression analysis it was shown that the contact pressure for any combination of ship and rock size can be expressed with a single normalized polynomial. The actual contact pressure was found by scaling the normalized pressure with the structural resistance coefficient. Given the formulation for the normalized contact pressure, the actual contact force for a ship can be found as a product of average contact pressure and the contact area.

The longitudinal length of the damage was evaluated based on the average contact force and the kinetic energy of the ship. The damage opening widths in the outer and inner bottom of the ship were derived separately for two ranges of relative rock sizes as they have strong influence on the deformation mode. The damage widths were given as a function of rock size, penetration depth and double bottom height. To improve the prediction of the onset of the inner bottom failure, a critical relative penetration depth as a function of the ratio of the rock size and the ship breadth was established.

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Comparison to the numerical simulations showed that the derived simplified approach describes the horizontal grounding force and the damage length well for the penetration depths above 0.5 m. For the range of specified relative rock sizes, the damage width in the inner and outer bottom deviates from numerical simulations approximately up to 25%, which was considered sufficient for the analyses where rapid damage assessment is needed. Comparison was also made to real accidental damage data and to the results of several simplified formulas.

Nomenclature

a	rock size parameter
A	contact area between the rock and the ship
B_a	rock width
c_T	parameter describing the ship structural resistance
δ	vertical penetration depth
D_{in}	opening width in the inner bottom plating
D_{out}	opening width in the outer bottom plating
d_{in}	inner opening width obtained from numerical simulation
d_{out}	outer opening width obtained from numerical simulation
F_H	average grounding force
dif_a	difference between rock width and numerical value (outer opening width)
DIF_a	difference polynomial for rock a
h_{db}	ship's double bottom height
L	ship length
p	value of contact pressure
P^i	function of contact pressure for a ship i
$\overline{P}(a)$	function of normalized contact pressure
S_{gir}	ship girder spacing
a/S_{gir}	relative rock size

1. Introduction

Increasing cargo flows all over the world have affected the density of marine traffic and thus risks for accidents. For example, in the Gulf of Finland oil transportation has quadrupled in the past ten years [1], which makes it a region of the highest risk in the world. However, the number of collisions and groundings with oil and chemical tankers in the mentioned region has stabilized [2], indicating the efficiency of existing measures towards increased safety at seas. As the traffic continues to increase, it is necessary to further improve various measures to keep the current safety level.

The most severe environmental consequences are caused by accidents with oil and chemical tankers, which in the worst case can lead to extensive oil spill. Accidents can be prevented and their consequences reduced by implementing safety measures that can be developed through risk analyses conducted for certain transportation areas. In a risk analysis, possible impact on the environment and human lives can be evaluated for typical accidental scenarios. To develop and test the safety measures, large numbers of accidental scenarios are to be analyzed. Thus, fast and sufficiently accurate tools are needed.