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M.Sc. Christian Woitzik,
Hamburg

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In the maritime sector, the collision safety is an essential aspect of ship operation. Aiming at further improvements, the filling of the cavity in a double hull structure with granular material is investigated in this thesis. In order to do so, the potential of different granules is determined experimentally, along with the description of their material parameters as particles and as a bulk material, respectively. Furthermore, a simplified side hull structure is designed for experimental testing, followed by a numerical study of different material models for the granules. This leads to the simulation of a realistic collision scenario, showing the potential in the maritime industry.

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Christian Woitzik, M.Sc.

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# Contents

# Abstract

In the maritime sector, the collision safety is an essential aspect of ship operation. In order to advance, new options have to be investigated. A recent idea is to fill the cavity in the double hull structure of a ship. To do so, this thesis provides fundamental research in this field.

Thus, the aim of this thesis is to investigate the potential of using granules as filling material based on experiments. Furthermore, the numerical modelling of these granules shall be investigated and verified.

In order to achieve this, several aspects have to be considered. Starting with the basic idea, suitable granules have to be determined. Therefore, a list of requirements is developed and experiments for the mechanical characterization of granules are developed. To describe the behaviour of single grains, a statistical approach is applied. The mechanical properties, such as crushing strength, and Young's modulus are determined using a single particle test assuming a Hertzian contact model. Based on this, a three-dimensional model covering the probability of the parameter distribution in combination with the diameter distribution is developed.

For the numerical modelling of the granules as bulk material, experiments such as oedometer test, triaxial test, and friction test are performed. This test data is used to calibrate and validate the numerical models used in this thesis. For the calibration, we use a numerical optimization to fit the material parameters to the experimental results, comparing these values with parameters obtained by identification using only experimental data.

One of the main aspect of this thesis is related to examine the potential of the granules used as filling material. Thus, a simplified side hull structure is designed for experimental testing. In these tests, reference experiments without granular material are performed. These are compared with structures containing granules. To do so, aside strain and displacement sensors, a digital image correlation system is used. In addition, we investigate the influence of the granules to stiffeners in the side hull structure. In doing so, the energy dissipation in case of a collision shall be increased.

The second main aspect refers to the numerical modelling of these experiments and the validation of different material models used for simulation. To do so, a continuum approach is applied, using the finite element method with explicit time stepping scheme. The granules are modelled using the Mohr-Coulomb material model and the hypoplastic material model, comparing the abilities of these in combination with the different material parameter sets. The advantages and disadvantages are discussed, leading to a recommendation for the application in finite element simulations.

In the last part of this thesis, we apply the numerical model to a mid-ship structure, comparing the two granules. Furthermore, we show possible changes in design, using the increase in collision resistance with granules. This addresses the potential in maritime industry, considering filling material in the design process of a ship structure.