VDI

REIHE 18
MECHANIK/
BRUCHMECHANIK

Fortschritt-Berichte VDI

M.Sc. Christian Woitzik,
Hamburg

NR. 356

Experimental testing and numerical simulation of granules as crash absorber for double hull structures

BAND
1|1

VOLUME
1|1

VDI

REIHE 18
MECHANIK/
BRUCHMECHANIK

Fortschritt-Berichte VDI

M.Sc. Christian Woitzik,
Hamburg

NR. 356

Experimental testing and numerical simulation of granules as crash absorber for double hull structures

BAND
1|1

VOLUME
1|1

VDI verlag

VDI verlag

Woitzik, Christian

Experimental testing and numerical simulation of granules as crash absorber for double hull structures

Fortschritt-Berichte VDI, Reihe 18, Nr. 356. Düsseldorf: VDI Verlag 2021.
142 Seiten, 134 Bilder, 17 Tabellen.
ISBN 978-3-18-335618-8, ISSN 0178-9457
52,00 EUR/VDI-Mitgliederpreis: 46,80 EUR

Für die Dokumentation: Kollisionssicherheit – Doppelhülle – Martime Anwendung – Crash-Absorber – Kollisionsversuch – Granulate – Expandiertes Glass-Granulat – Experimentelle Untersuchung – Finite-Elemente-Methode

Keywords: Collision safety – Double hull structure – Maritime applications – Crash absorber – Collision test – Granules – Expanded glass material – Experimental testing – Finite element method

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.

Bibliographische Information der Deutschen Bibliothek
Die Deutsche Bibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliographie; detaillierte bibliographische Daten sind im Internet unter www.dnb.de abrufbar.

Bibliographic information published by the Deutsche Bibliothek (German National Library)
The Deutsche Bibliothek lists this publication in the Deutsche Nationalbibliographie (German National Bibliography); detailed bibliographic data is available via Internet at www.dnb.de.

Arbeitsgruppe Numerische Strukturanalyse mit Anwendungen in der Schiffstechnik

ISBN 978-3-18-335618-8, ISSN 0178-9457

Experimental testing and numerical simulation of granules as crash absorber for double hull structures

Vom Promotionsausschuss der
Technischen Universität Hamburg

zur Erlangung des akademischen Grades

Doktor-Ingenieur (Dr.-Ing.)

genehmigte Dissertation

von
Christian Woitzik, M.Sc.

aus
Hamburg

2021

Vorsitzender des Prüfungsausschusses
Prof. Dr.-Ing. Thomas Rung

Gutachter
1. Gutachter: Prof. Dr.-Ing. habil. Alexander Düster
2. Gutachter: Prof. Dr.-Ing. habil. Dr. h.c. mult. Dr.-Ing. E.h. Peter Wriggers

Tag der mündlichen Prüfung: 3. August 2021

Acknowledgements

This thesis is the result of my work at the Institute for Ship Structural Design and Analysis (M-10) at Hamburg University of Technology (TUHH). It was funded by the Deutsche Forschungsgemeinschaft (DFG) in the period from October 2015 to February 2020 and was carried out in cooperation with the Leibniz University Hannover. Many people contributed to my work and supported me during this time – and I would like to thank all of them for their help.

First, I would like to express my gratitude to Prof. Dr.-Ing. habil. Alexander Düster, the supervisor of this work. Dear Prof. Düster, your expertise, your helpfulness and our fruitful discussions were a great support during my time working with you. I would also like to thank Prof. Dr.-Ing. habil. Dr. h.c. mult. Dr.-Ing. E.h. Peter Wriggers – for acting as co-supervisor for this thesis and for his ideas and helpful comments during several project meetings – and Prof. Dr.-Ing. Thomas Rung for chairing my PhD-examination.

Further, I would like to thank all my colleagues: First of all, my project partner Mohsin Chaudry from the Leibniz University Hannover, who was always open to discussions. Next, the colleagues in our laboratory, as well as from other institutes, who helped me a lot with the experiments and invested a lot of their free time to do so. And of course, all my colleagues at M-10, who have always been an inspiration and made my time at the university very pleasant.

Last but not least, my heartfelt thanks go to my family and friends for their moral support. In particular, I want to thank my beloved mother. Thank you for your endless love, faith, and support in my life.

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.