StaProCrash

Development and manufacture of crash-optimized multi-chamber steel structures by roll forming

Coordinator	Johannes Kilz M. Sc.
Duration	June 2022 – September 2024
Department	Profile Manufacturing Technology
Funded by	BMWK | AIF | IGF | FOSTA

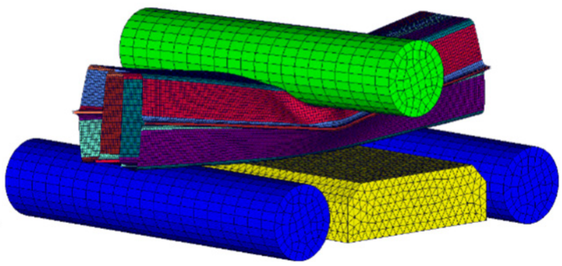
Abstract

As part of this research project, which was conducted in collaboration with the Chair of Optimisation of Mechanical Structures (OMS) at the University of Wuppertal, methods were developed for the efficient design of roll-formed, crash-optimised profile structures. Initially, various high-strength steels were examined for their behaviour during roll forming and for their residual deformation capacity. Based on this, the algorithm of the graph and heuristics-based topology optimisation (GHT) was adapted by the OMS in order to optimise the cross-sectional geometry of roll-formed multi-chamber structures made of high-strength steel. Final drop tower tests with demonstrators designed by the GHT and subsequently manufactured show a very good correlation between simulation and actual behaviour.

Project description

As part of the project, material characterisations were initially carried out with various high-strength steels in order to determine the influence of roll forming on the strength and the ability of the structures to absorb energy. In addition, roll forming simulations were implemented for various profile cross-section geometries and multi-chamber structures in order to be able to analyse the material behaviour during roll forming in more detail. The data obtained served as a basis for the OMS project partners to adapt a GHT algorithm developed for extruded profiles to optimise the cross-section geometry to the requirements and material behaviour of roll-formed crash structures. The objective is to optimise the cross-section of a roll-formed multi-chamber structure in order to achieve the highest possible energy absorption with the lowest possible weight. When designing roll-formed crash structures using the adapted GHT, cross-sections are generated by iteratively inserting a further roll-formable sheet metal structure into the available design space and crashing the resulting structure in a simulation with a previously defined load case. The crash performance is then evaluated automatically and the cross-section is iteratively adjusted until the specified crash performance is achieved.

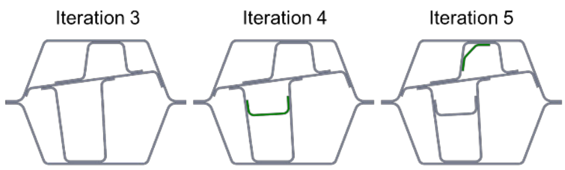
To validate the simulation and the GHT, the load case shown in Figure [1], in which the lateral impact on a pile is simulated, was selected together with the project committee. The aim of the optimisation in this case is to absorb the total force acting on the supports and the battery cell behind the crash structure (yellow block) as evenly as possible while keeping the weight of the crash structure low. The results of the optimisation are the demonstrators shown in Figure [2], which were finally manufactured and crashed in drop tower tests.



[1] Selected load case for validation

Results

The initial material characterisation showed that roll forming does not have a negative effect on the remaining deformation capacity of the materials at specific bending radii tested. The roll-formed samples, which were subsequently tested in tensile-tests until failure, exhibit the same tensile strength under the selected parameters as the non-preloaded material. This indicates that there is no need to adjust the material properties in the crash simulation for the selected bending angles and radii. The GHT was adapted by the OMS. Among other things, the OMS developed new algorithms to evaluate the manufacturability using roll forming and laser welding of the structures generated by the GHT. In addition, various methods were developed to automate the insertion of roll-formed sheets and welding positions. Finally, the GHT adapted to roll forming was used to optimise the load case shown in Figure [1]. Figure [2] shows the various iterations of a cross-sectional structure that was generated by the GHT and fulfils the requirements in terms of weight and maximum forces.



[2] Optimisation iterations selected for demonstrator

For validation purposes, the structures shown were manufactured at the PtU by roll forming, die bending and laser welding. This showed that the required minimum bending radii are undercut by the die bending, which leads to weakening of the material.

Institute for Production Engineering and Forming Machines – PtU
Prof. Dr.-Ing. Dipl.-Wirtsch.-Ing. Peter Groche | info@ptu.tu-darmstadt.de

Finally, drop tower tests show the good agreement of the force-displacement curves during the crash between simulation and test and thus demonstrate that valid, crash-performing, roll-formed structures can be generated with the aid of the GHT adapted to roll forming.

Acknowledgement
The research work presented here takes place within the framework of IGF project no. 23320N of the research association Europäische Forschungsgesellschaft für Blechverarbeitung e.V. (EFB). This is funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) via the German Federation of Industrial Research Associations (AiF) as part of the program for the promotion of joint industrial research (IGF) on the basis of a resolution of the German Bundestag.

Furthermore, we would like to thank all industrial partners who support the research project “Profile straightening by partial rolling” in the project accompanying committee.

Funded by

Project Partners

Institute for Production Engineering and Forming Machines – PtU
Prof. Dr.-Ing. Dipl.-Wirtsch.-Ing. Peter Groche | info@ptu.tu-darmstadt.de

Project Partners