Lars Molter: Fatigue Strength of Laser Hybrid Weld Seams in Ship Construction

The aim of the present thesis is to reveal and assess the parameters influencing the fatigue strength of thin welded steel butt joints. Especially regarding plates with a thickness below 5.0 mm the shipbuilding industry is short on experience. However, the application of thinner steel structures is becoming more important due to the potential savings in the ship's deadweight. For applying thin plates in load carrying ship structures, the class societies recommend to show their equivalency in terms of structural safety in comparison to thicker plates. One major issue in marine structures is fatigue. During the usual lifetime of 20 years, such structures bear up to several million load cycles. It is essential that new structural details, like thin welded plate joints, are assessed with respect to fatigue and its influencing factors. Therefore, the present work is based on experimental data retrieved from 3.0 mm thick steel plates welded by laser, laser-hybrid and MAG techniques and complemented by a numerical-based fatigue and statistical assessment. In addition, a sensitivity analysis is applied to reveal the influence of each single parameter on the fatigue strength. Beside the geometrical parameters, the material in the different weld zones is evaluated in terms of a potential influence on the fatigue strength.

By assessing the geometrical data from the specimens in terms of their occurrence probability as well as evaluating their values with respect to the limits given by quality standards (e.g. DIN 5817), the main characterisation of the specimens is revealed. Hereafter, the fatigue tests demonstrate the fatigue strength and the results are compared to the shipbuilding standards and rules, e.g. GL, IIW. Furthermore, local fatigue assessment methods are applied to evaluate the different factors influencing the fatigue strength on the one hand, and to validate the assessment methods with respect to thin structures on the other hand.

The results of this thesis demonstrate the relation between the factors stated in the quality standards and the fatigue strength. A high quality of the weld leads to a high fatigue strength as shown by the laser welded specimens. In addition, the material analyses reveal no significant influence, at least compared to the dominating misalignment parameters as well as undercuts. Moreover, the fatigue assessment methods have proven partially feasible for assessing thin structures. Especially the notch stress method reveals difficulties with smooth weld geometries. It is recommended by this work that the use of the assessment methods needs to be accompanied by an evaluation of its feasibility with respect to its theory.

In summary, the present work demonstrates the fatigue assessment of welded thin plate structures with a high fatigue strength for laser welded specimens in comparison to the other methods. Moreover, the analyses reveal the significance of the misalignments with respect to the fatigue strength and evaluate the state of the art fatigue assessment methods for evaluating thin plates.