

On the Fatigue Strength of Thin-Plated Ship Structures

Ship structures are subject to wave induced cyclic loading with high load amplitudes throughout the design life of about 20 to 25 years. With the repeated loading, even below the yield point of the material used, fatigue cracks are initiated, propagate and finally may lead to the loss of a structural detail or even more severe damage. Furthermore, thin-plated ship structures of 5.0mm thickness and less imply several challenges in design and production. Production related misalignment and local weld shape influence the fatigue life. To assess the design life of welded connections and structural details, fatigue testing is carried out on single weld details or even full-size structures.

The present work focuses on fatigue strength assessment of 5.0mm thick butt-welded joints, typically a part of the deckhouse or superstructure of seagoing ships. Furthermore, fatigue assessment was carried out on fillet-welded structural details with a plate thickness of 3.5mm. These so-called 'floating frame' joints are part of the main framing system of small High Speed Light Craft and work boats. The floating frame is not included in the recommendations by the International Institute of Welding and rules and regulations of ship classification societies, but as fatigue related cracks were reported from ships in service, integration of the design floating frame design should be considered in the future. Constant amplitude fatigue testing of both joint series was carried out at the fatigue strength laboratory of Kiel University of Applied Sciences.

Submerged arc welding was used for the butt-welded joints made of steel grade AH36 with yield strength of 355 N/mm². Geometry scans were carried out using a 3D CNC coordinate measuring system. In addition, the gas metal arc welded floating frame joints, made of mild steel with yield strength 235 N/mm², were recorded using 3D laser scanning technique.

The fatigue strength assessment was carried out based on the experimental data as well as based on numerical finite-element-analyses. With help of the structural stress analysis, the geometrical influence of the joints, e.g. misalignment of plates and the weld shape could be taken into account. Moreover, the influence of welding defects such as undercuts on the fatigue life was assessed with the help of different notch stress concepts. Based on the outcome of the fatigue assessment, the undercut as well as the toe radius and weld throat angle on the load-carrying side of the weld were identified as main influencing factors on the fatigue strength of the fillet-welded floating frame joints. For the butt-welded joints the angular and axial misalignment was identified as a major driver of the fatigue strength along with the undercuts. Furthermore, the usage of a shallower slope $m=5.0$ instead of $m=3.0$ for SN-curves based on notch stress analysis was indicated by the combined results of butt- and fillet-welded joints.