Numerical Modelling of Welding Induced Stresses

Enormous amounts of welds are made in rather heavy steel sections of a great deal of modern engineering applications. In many cases better tools for calculating the mechanical or structural response of these constructions taking into account the residual stress state from the manufacturing processes (e.g. that of welding), would make cost down initiatives possible.

The overall objective of this thesis is to propose a procedure providing useful calculations of residual stresses in welded industrial structures. The welds are restricted to those used in rather heavy sections and the welding processes are limited to conventional arc welding processes, especially submerged arc welding.

Two applications are in focus, the first serving as a principal case adequately simple from a technological point-of-view. It consist of two plates, 240 mm x 480 mm with a thickness of 10 mm, butt welded in both one and two passes. The second application is a frame box structure forming part of a large two-stroke diesel engine. It comprises four welds, each welded in four passes and plate thickness varying between 25 mm and 60 mm.

A three-dimensional model is presented for the analysis of the butt weld application. Special attention is paid the influence of the initial stress state before welding, that is, the residual stress state after preparation of the plates by flame cutting. The generalized plane strain assumption is applied the model for analysing the frame box application. The model is used as an approach to estimate the fatigue strength of the as-welded structure compared to a stress relieved/free structure.

Thermo-couple measurements, neutron diffraction measurements and hole-drilling strain gauge measurements are utilized to thoroughly verify the numerical modelling. Extensive laboratory fatigue tests are carried out in connection with the frame box application.

An important issue in numerical modelling is to decide which effects, as minimum, must be included to adequately obtain the goal. Before the applications are considered in details, the many complicated and strongly coupled phenomena in the modelling of welds are presented; geometrical considerations are described; numerical methods applicable for the solution of physical problems as that of simulating the welding process are presented; the governing equations for the thermo-mechanical analysis are outlined; the boundary conditions and material modelling are treated for the thermo-mechanical analysis; and finally, the key task of modelling the moving heat source is discussed.